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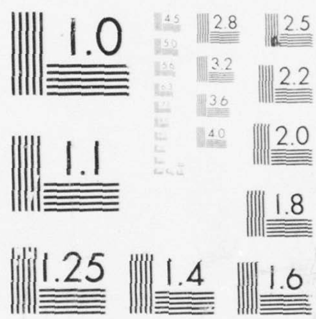

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Technical Report 288

PITI POWER PLANT INTAKE SURVEY
NOVEMBER 1977

JG Grovhoug

15 September 1978

Prepared for

Naval Facilities Engineering Command
Pacific Division
Pearl Harbor, Hawaii

U. S. Naval Public Works Center
Guam

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NAVAL OCEAN SYSTEMS CENTER
SAN DIEGO, CALIFORNIA 92152

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Technical Director

ADMINISTRATIVE STATEMENT

Funds for this survey were provided by the Naval Facilities Engineering Command, Pacific Division, Code 114 under Project No. N6274277P000C29. Personnel from the Naval Ocean Systems Center, Hawaii Laboratory performed the on-site field survey in Guam and prepared this final report. R. Scott Henderson and Thomas J. Peeling reviewed this document for technical accuracy.

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A marine environmental field survey was conducted during November 1977 at Piti Power Plant, Guam, Marianas Islands. Descriptive data were obtained for benthic, nektonic and planktonic components of the resident ecosystem. Analysis of survey data consistently suggests that negligible environmental impact is directly attributable to the intake structure design and operation. The marine ecosystem adjacent to the Piti Plant supports a complex and diverse Cont

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20. Abstract. (continued)

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biotic assemblage. An examination of representative important species indicates that many taxa are provided with additional suitable habitat by the intake waterways and associated structures. Tabulations of data collected, checklists of organisms identified and detailed descriptions of marine environmental survey techniques used during the survey are presented in the text and appendices of the report.

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EXECUTIVE SUMMARY

This report describes a study performed at the U. S. Navy Piti Power Plant located at the Cabras Island Causeway adjacent to Apra Harbor on the island of Guam. Naval Ocean Systems Center personnel conducted this field survey at the request of the Naval Facilities Engineering Command, Pacific Division. In compliance with the provisions of PL-92-5200, section 316(b), a study was undertaken to determine marine environmental conditions affected by the Piti Power Plant intake structures.

Analytical interpretation of data strongly supports on-site field observations made in November, 1977. Data collected during this study indicate that negligible environmental impact is attributable to the intake structures at the Piti Plant. This determination has been consistently supported through analyses of planktonic, nektonic and benthic communities in Piti Canal, Tepungan Channel and the immediate vicinity of the Piti intakes. Physical and chemical water quality parameters measured during the survey further support this evaluation.

A checklist consisting of more than 275 faunal and floral taxa was assembled from observations, photos and collections in the intake environments. The populations of marine organisms inhabiting Piti Canal, Tepungan Channel and adjacent reef flat areas are complex and diverse. Two sets of previously reported productivity measurements (Marsh, 1974 and 1977) indicate that functional characteristics of the Tepungan reef flat ecosystem are of the same order of magnitude as values reported for other Pacific coral reef communities. Values for the Piti reef flat are remarkably similar to those measured for a Hawaiian (Kauai) reef flat ecosystem (Kohn and Helfrich, 1957).

Measurements obtained before and after tropical storm Kim provided an additional perspective and range of near-typhoon conditions and subsequent effects on biota in the study area. Both direct and indirect effects on Guamanian marine environments are to be expected from periodic exposure to typhoons (Randall and Eldredge, 1977).

A list of representative important species from Piti intake environments is proposed. These selected biota represent a wide range of taxonomic diversity, feeding types and habitat requirements. A discussion of potential effects attributable to intake structures on these groups is provided.

ACKNOWLEDGEMENTS

The author thanks the following individuals for their support during the survey, analytical and reporting phase of this study: R. Scott Henderson, NOSC, for energetic assistance with all phases of on-site survey activities, preparation of Appendix A and providing review and comments concerning the manuscript; Charles T. Peterson, NOSC, for on-site photographic documentation and assistance with many survey tasks; LCDR Robert Norris, Operations Officer, PWC Guam, for outstanding logistics support throughout the survey; Frank Mata for allowing the survey team to use his laboratory within the Piti Plant and for providing useful plant data; Hill Guerrero, Piti Plant Foreman, for his cooperation with various sampling activities; Ralph Lytle, PWC Fena Lab, Guam, for loaning the survey team a boat and motor and performing nutrient analyses; Ed Rastetter for providing much appreciated opinions on statistical matters and for helping to fabricate and assemble equipment prior to the survey; Bill Cooke, Pam Ching, Bob Cutts and Linda Ward for performing biological sample processing including identification and enumeration and Wim Kimmerer, HIMB, for completing the analyses of zooplankton samples in a timely and high quality manner.

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INTRODUCTION

Pursuant to the provisions of Public Law 92-500, Section 316(b), the Naval Facilities Engineering Command, Pacific Division, requested a proposal from the Naval Ocean Systems Center, Hawaii Laboratory, for a study of potential impacts on the marine environment by the Piti Power Plant intake structures. A survey proposal was prepared by NOSC and accepted by PacDiv during the summer of 1977. This report documents the results of a survey conducted in November 1977 at the Piti Power Plant, Guam.

The Piti Power Plant has been the major source of power in Guam since construction was completed for Units #1, #2 and #3 in 1952. Increased power demands dictated the further construction of Units #4 and #5, which was completed in 1968. Additional requirements for power resulted in the construction of the Guam Power Authority's Cabras Island Power Plant. This new plant became operational in May 1975. The Cabras Plant, consisting of two large units, is rated at a total power generating capacity of 132 megawatts. The older Piti Plant has a combined total rated capacity of about 74 megawatts (Marsh, 1977). The Piti and Cabras Island Power Plants are both situated adjacent to the Cabras Island Causeway. Intakes for the Piti and Cabras Plants are located about 200 meters apart in Piti Canal. These plants draw cooling water directly from Piti Canal which in turn is supplied by Tepungan Channel on the east and a connection with the Philippine Sea from the northwest. Oceanic, low-nutrient, open coastal seawater is utilized as a condenser cooling medium in both the Piti and Cabras Plants.

Tepungan Channel and Cabras Island are natural features which have undergone extensive human alteration during the last thirty years. Until the Cabras Island causeway was constructed during the period 1940-1947 (Tudor Engineering Company, 1964), there was a natural flow of water from West Piti Bay through Tepungan Channel into Apra Harbor (see Figure 1, a reproduction of USC&GS Chart 4202, showing conditions in June, 1941). Piti Canal was constructed (circa 1950) in conjunction with the Piti Power Plant construction schedule.

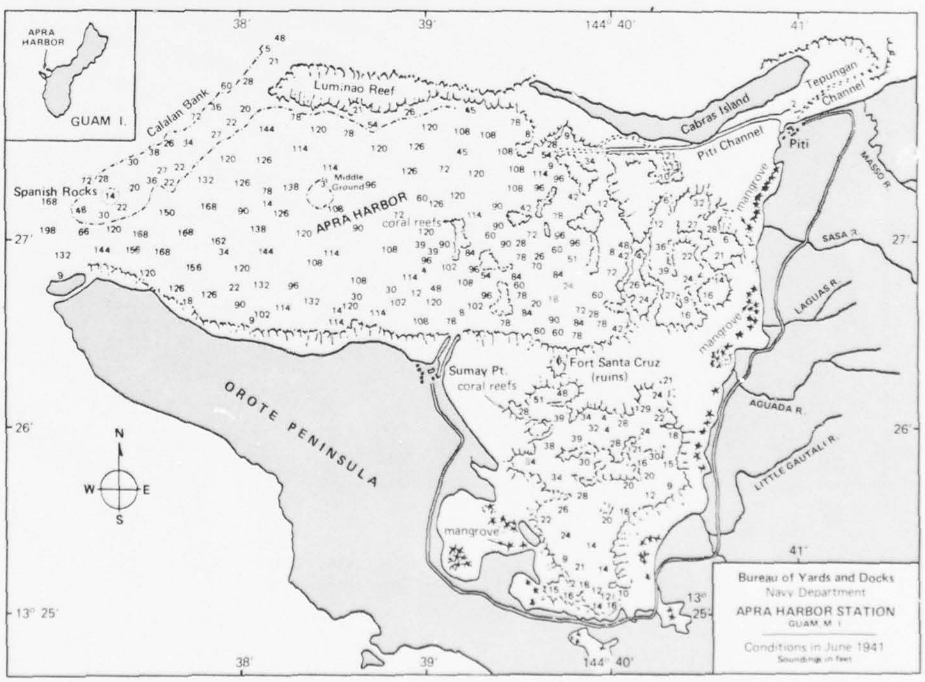

Figure 1. Conditions in Apra Harbor, June 1941.

Oceanic water from the Philippine Sea enters Piti Canal, a man-made cooling-water passageway approximately 600 meters long, and moves in a southeasterly direction toward the Piti Power Plant. Additional oceanic water enters Tepungan Channel through West Piti Bay and travels southwesterly, passing under the Cabras Island Causeway and empties into Piti Canal via two channel arms. Tepungan Channel was widened and deepened to a mean depth of five meters during the period December 1972 through April 1973 (Marsh, 1975). At this time a new northwest arm was dredged for cooling-water diversion to the Guam Power Authority Cabras Island Power Plant (see Figure 2).

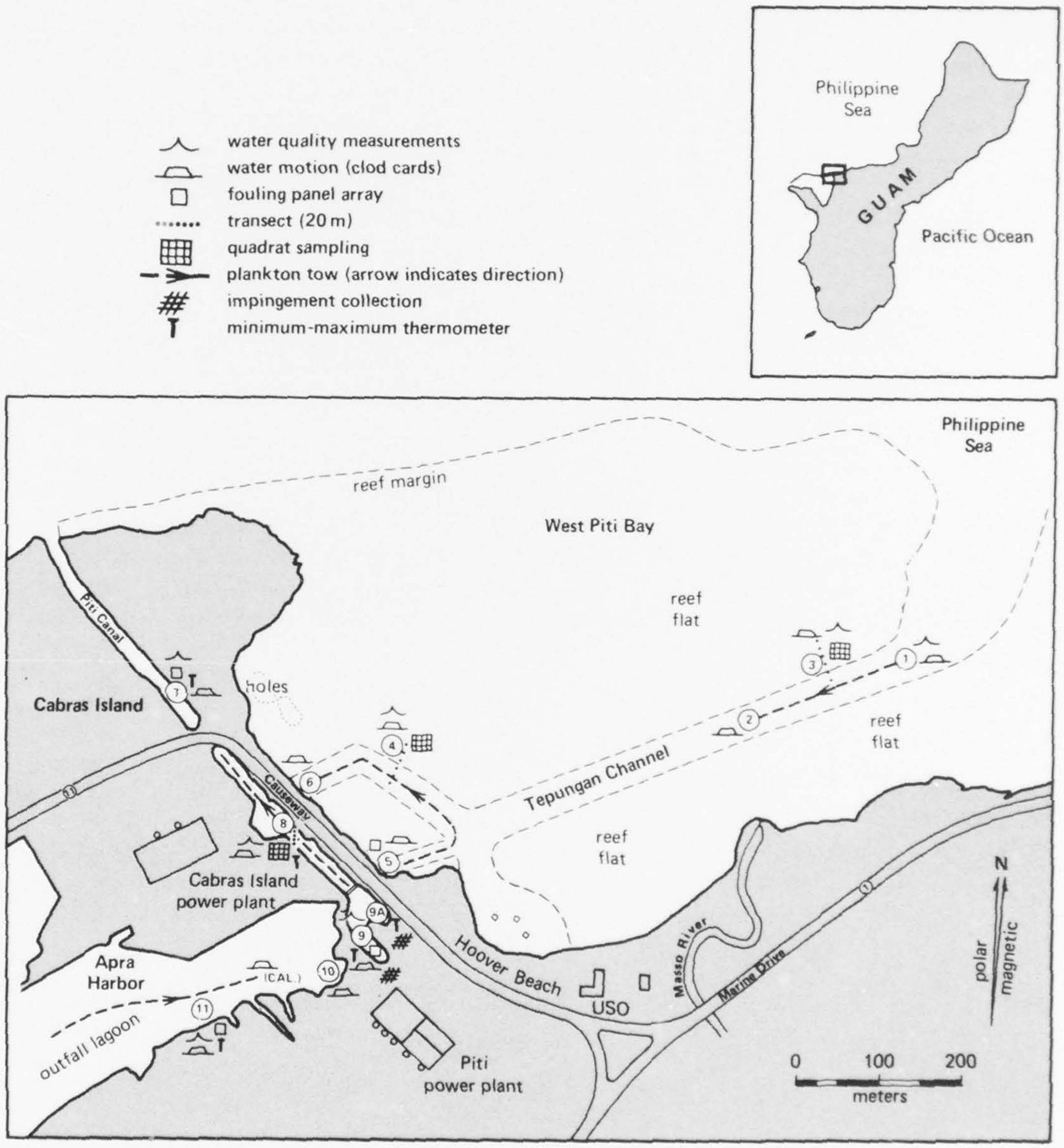

Figure 2. Major features of the study area (including station location and sampling activities), Piti Power Plant Intake Survey, November 1977.

The primary intake area for the Piti Power Plant is located at the eastern termination of Piti Canal. Here the canal bifurcates into northern and southern arms. The southern arm diverts cooling water to units #1, #2 and #3. During the November 1977 survey only unit #2 was in operation. The turbine and generator for unit #1 are permanently out of operation and unit #3 was being repaired. The northern arm directs cooling water into Piti units #4 and #5. Cross-channel dimensic of the intake structure between the bar grates and traveling screens are seven meters wide by five meters deep. The intake structure for units #1, #2 and #3 has cross-channel dimensions between the bar grates and traveling screens of four meters wide by five meters deep. Screening devices consist of the coarse bar grates (10.2cm spacing) which are located about four meters ahead of the 8mm square mesh traveling screens.

The intake waterways (Piti Canal and Tepungan Channel) are utilized by both the Piti and Cabras Island Power Plant Facilities as a source for cooling water. This situation complicates an impact evaluation for either plant alone. Maximum cooling water flow volumes for the Piti and Cabras Plants are 4.85 cubic meters/second (64,000 GPM) and 9.01 cubic meters per second (120,000 GPM), respectively (Marsh, 1977).

Base-line environmental studies prior to the construction and operation of Piti Power Plant do not exist; therefore, stations were selected at the initiation of this study after on-site reconnaissance observations had been made. The most relevant studies in the vicinity of the intake areas were performed by Dr. James A. Marsh *et al.*, University of Guam, during the period 1971–1977. Two former plankton sampling stations (Piti Canal and the Outfall Lagoon) were sampled for comparative purposes during the present study.

Prior to arrival on-site, a review of pertinent information including literature, documents, drawings, permits, photographs and charts of the area was performed. Various survey support requirements were transmitted to PWC Guam in advance. A preliminary plan for anticipated survey activities was prepared. This plan was highly useful for the efficient allocation of field time, especially when tropical storm Kim temporarily interrupted survey activities during 8 and 9 November 1977.

Selection criteria for sampling stations utilized during the Piti Power Plant Intake Survey focused on locations which provided representative environmental conditions in the study area. Twelve locations were chosen to perform at least one, but more often, multiple sampling activities. Ten of these sites were "upstream" of the power plant intakes. Additionally, two stations were located "downstream" in the outfall lagoon. Station and activity reference locations are shown in Figure 2. Station designation, geographic coordinates, sampling activity and a brief habitat description for each station are summarized in Table 1. A synoptic Piti Survey activity matrix is presented as Table 2.

METHODS

Zooplankton (including larval fish and fish eggs) samples were collected using a 50cm diameter, 243μm mesh (Nitex) net with a simple conical configuration and a 5:1 length to diameter ratio. All plankton tows were metered using eccentrically mounted General Oceanics Model 2030–R2, oil-filled, digital flow meters to accurately measure the volume of water filtered. Zooplankton and larval fish samples were collected from one meter below the surface during each tow of eight minutes duration. This towing interval was selected after trial runs at the desired towing speed along the shortest segment to be sampled (located in Piti Canal,

Table 1. Station designation, location, sampling activities & descriptions, Piti Power Plant Intake Survey, November 1977.
Legend: I/D*=Intake/Discharge side of Piti Plant;
Activity**: FP=fouling panel, IM=impingement collection, OB=diving observations, PL=plankton collection, QU=quadrat sampling, TM=minimax thermometer, TR=transect sampling, WM=water motion (clod-cards), WQ=water quality (including: nutrients, dissolved oxygen, temperature & salinity).

Station #	I/D*	Latitude (N)/ Longitude (E)	Activity**	Description
1	I	13°27′55.62″ 144°41′29.8″	PL/OB/WQ/WM	Outer Tepungan Channel, mid-channel @ stake; depth: 5m; sand & rubble bottom.
2	I	13°27′53.08″ 144°41′23.5″	PL/OB/WM	Outer Tepungan Channel, mid-channel; depth: 4.5m; sand.
3	I	13°27′56.36″ 144°41′25.6″	QU/TR/WQ/WM	Outer Tepungan Channel, on reef flat; depth: 1.5m; hard bottom, algae, coral & rubble.
4	I	13°27′51.53″ 144°41′9.3″	OB/QU/TR/ WQ/WM	Inner Tepungan Channel, on reef flat; depth: 1.5m; sand & rubble.
5	I	13°27′46.82″ 144°41′9.5″	FP/PL/OB/WM	Inner Tepungan Channel, at causeway (near USO swimming area); depth: 5m; sand bottom.
6	I	13°27′49.93″ 144°41′6.0″	PL/OB/WM	Inner Tepungan Channel, north arm, at causeway; depth: 6m; sand & rubble bottom.
7	I	13°27′53.00″ 144°41′0.7″	FP/PL/OB/WQ/ TM/WM	Piti Canal, seaward end (N); depth: 5m; coral, algae, rubble and sand bottom.
8	I	13°27′48.23″ 144°41′5.3″	PL/QU/TM/TR/ WQ/WM	Piti Canal, adj. to Cabras intakes; depth: 4.5m; rubble, debris & sand bottom.
9	I	13°27′43.86″ 144°41′8.7″	FP/PL/OB/IM/ TM/WQ/WM	Piti Canal, southwest arm at intakes, units 2 & 3; depth: 5.5m.
9A	I	13°27′44.75″ 144°41′9.3″	IM/OB/TM	Piti Canal, northeast arm at intakes, units 4 & 5; depth: 5.5m.
10	D	13°27′43.11″ 144°41′7.1″	PL/OB/WM	Piti Outfalls: unit 2; units 4 & 5; depth: 6m; rubble & algae.
11	D	13°27′40.32″ 144°41′2.3″	FP/PL/OB/TM/ WQ/WM	Outfall Lagoon, along south bank; depth: 2m; silty sand bottom; at abandoned wooden barge.

Table 2. A synoptic activity matrix for the Piti Power Plant Intake Survey performed in November 1977.

Sampling Activity	NOVEMBER 1977 2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Nekton															
- UOCCP		X	X	X					X	X	X	X			
- Transects									X						
- Impingement sampling			X	X	X	X				X		X			
Benthos															
- UOCCP*		X			X				X			X			
- Transects									X						
- Quadrat Sampling									X						
- Infaunal Sampling					X				X	X	X	X			
- Epifaunal Sampling (fouling panels)		X –	–	–	–	–	–	–	–	–	–	–	–	X	
Plankton															
- Entrainment sampling (tows)			X	X		X					X		X		
Water Quality															
- Temperature (point)			X	X		X			X		X		X		
minimax					X –	X –	–	–	X –	X –	–	X –	–	X	
- Salinity															
samples						X					X				
refractometer			X		X	X			X		X		X		
- Dissolved O_2				X		X					X		X		
- pH (plant data)		X –	–	–	–	–	–	–	–	–	–	–	–	X	
- Nutrients															
NO_3				X		X					X		X		
NH_4				X		X					X		X		
PO_4				X		X					X		X		
- Water Motion (clod cards)				X –	–	X –	–	–	X	X –	–	X –	–	X	
calibration												X			
Pre-Survey	–	–	X												
Station Selection		X –	X												
U of Guam										X					
GEPA Contact										X	X				
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Arrival 1550 Guam (K) time

Tropical Storm Kim

Departure 1515 Guam (K) time

*UOCCP = Underwater observations, counts, collections & photography.

see Figure 2). A stop-watch was used for precise timing of each towing interval. The net was towed at a distance of ten meters behind a small outboard powered skiff (see Figure 3) at a speed of approximately 1.5 knots during the first fifteen tows; the two remaining "tows" were taken by suspending the net in each outfall plume for a period of eight minutes. One nighttime plankton tow was taken for comparative purposes. All other tows were performed during the day at or near high tidal conditions. Samples were preserved in 5% seawater-formalin in the field immediately upon collection. Laboratory analysis for all plankton samples was performed in Hawaii by Mr. Wim Kimmerer, Hawaiian Institute of Marine Biology (University of Hawaii). Standard laboratory zooplankton analytical techniques were utilized to obtain data for settled volumes, species identification and enumeration. This procedure consisted of dividing each sample into one quarter aliquots using a Folsom Plankton Splitter after large pieces of benthic algae (mostly *Sargassum*) had been removed. All zooplankton and fish eggs were counted from one or two aliquots. In some instances additional aliquots were examined, and all zooplankton enumerated except foraminifera, fish eggs and gastropod veligers. For sample #11, the Piti Canal nighttime collection, aliquots of 1/40th each were taken by means of a Stempel pipet. Settled volumes were determined by removing the detritus and algal components. The samples were next settled in a graduated cylinder for several hours and a value to the nearest half a milliliter recorded. Except for sample #11, settled volumes were so small (less than 0.5 ml for the total sample) and detritus loading so great, that settled volumes for the remaining sample were estimated. All organisms were identified to the lowest taxonomic level possible within the time constraints of the reporting schedule. A question mark (?) preceding a generic or specific epithet indicates that the taxonomic identification for that organism is questionable.

Figure 3. Completing a zooplankton collection in Piti Canal, Piti Power Plant Intake Survey, November, 1977.

Impingement samples were collected using cylindrical hardware-cloth baskets (25cm diameter, 6mm square mesh galvanized wire) fabricated on-site. These collection baskets were placed in the traveling screen sluice channel (see Figure 4) for a collecting interval of fifteen minutes daily at each intake structure. Traveling screens were placed in operation only once each day during the survey period to facilitate maximum sampling of impinged organisms. Above and underwater observations were made at the vertical bar grates located on the seaward side of the intake structures to observe potential impingement of larger biota. Existing removable 10mm mesh framed screens located in the upper two meters of water just outside the larger bar grates provided an additional impingement surface for observation. Material from the collection basket was examined immediately after each daily sampling period. Any fishes or macroinvertebrates were enumerated and selected individuals were preserved in 10% seawater-formalin for further laboratory examination. An estimation of the amount of drift algae collected was recorded after each impingement sampling period.

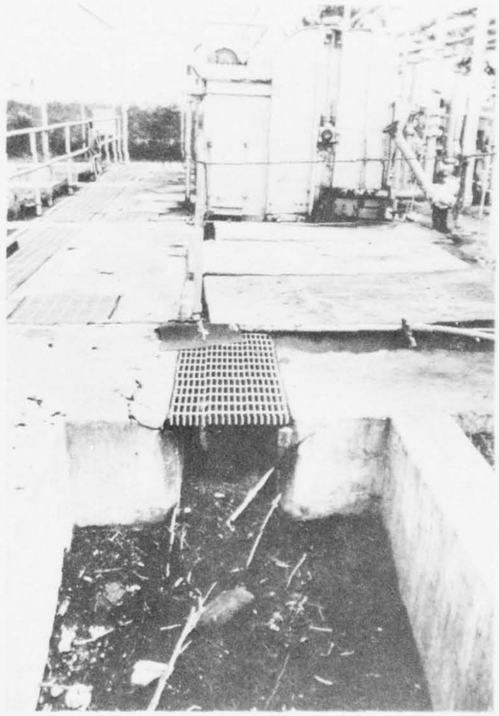

Figure 4. Traveling screen sluiceway at Piti intakes for units 4 and 5 used for impingement sampling during Piti Power Plant Intake Survey, November, 1977.

Nektonic organisms (e.g., free swimming fishes and macroinvertebrates) were sampled non-destructively by means of underwater visual observations, counts and photography during the survey period. Extensive underwater observations were made in Piti Canal, Tepungan Channel and over adjacent reef flat areas. A series of fish and benthic macroinvertebrates transects were conducted at selected sites. Each transect consisted of identifying and enumerating biota along a two-meter by twenty-meter corridor. Transects were aligned to sample reef top, slope and channel bottom habitats. Observations were recorded on underwater slates which carried plastic-impregnated paper, thus providing a permanent data record.

Benthic biota in Piti Canal and Tepungan Channel were sampled by underwater visual observations, photography, transect and quadrat techniques (see Figures 5 and 6). A series of transect/quadrat observations were performed at the same locations used during fish transect sampling. Collections of selected benthic organisms were made to obtain reliable taxonomic identifications. Fouling panel arrays were placed at three locations in Piti Canal and Tepungan Channel to provide a two-week settlement record for the intake areas. Each array consisted of three, 15x15cm, roughened PVC panels mounted on a plexiglas backing plate using nylon screws. These arrays were vertically positioned a meter below the surface of the water at high tide. The two arrays in Piti Canal experienced a western full sunlight exposure; the array at the junction of Tepungan Channel and Piti Canal (Station 5) received no direct sunlight. Laboratory analyses for biotic constituents of the fouling community were performed in Hawaii using material on the panels which was preserved in 10% seawater-formalin immediately upon collection in Guam. Microscopic examination and scrapings provided species identification and abundance estimates for epibiota in the intake areas.

Figure 5. Quadrat Sampling in Tepungan Channel (reef flat).

Figure 6. Quadrat Sampling in Tepungan Channel (slope).

Water column physical and chemical data were collected at selected stations during the survey (see Figure 2). Parameters measured to evaluate water quality include: Temperature (°C); Salinity (‰); Dissolved oxygen (mg/L); pH, Nutrients, NO_3-N, NH_4-N, PO_4-P (µg-atoms/L); and integrated water motion, using clod-cards (cm/sec). Temperature data were recorded for outlying, immediate intake and discharge areas (within the plant and in the discharge lagoon). Hand-held, shielded mercury thermometers, minimum-maximum thermometers and a YSI Telethermometer (Model 42SC) were used at various stations to measure water temperature (to the nearest 10th of a degree Centigrade). Salinity measurements were taken in the field using a temperature-corrected AO refractometer. Discrete salinity samples were also collected from selected stations and shipped back to Hawaii where determinations were made on a Plessey Environmental Systems Model 6230N laboratory conductivity salinometer. Oxygen data were measured in the field using a YSI Model 57 portable dissolved oxygen meter with battery-operated stirrer. Readings from surface, one and two meter depths were profiled at each selected station on four different days during the survey. pH values were determined at the water quality lab within Piti Power Plant on an hourly basis. A Beckman laboratory pH meter was utilized by plant personnel for these determinations. Nutrient samples were collected at selected stations. Approximately 120ml of seawater were collected in well rinsed plastic bottles from a depth of half a meter. Samples were immediately filtered in the field through Whatman GF/C filters and placed on ice. All nutrient samples were frozen upon return to the laboratory, usually within one hour of collection. Analyses were performed by the PWC Guam, Fena Laboratory using a Technicon II Autoanalyzer.

Water motion was measured at all stations several times during the survey using clod-cards of a newly-developed formulation. A value for water motion (cm/sec) integrated over a period of several days was obtained using the dissolution and attendant weight loss of rectangular clods constructed of carpenters "Fixall" and plastic resin glue (see Appendix A for a more complete discussion). A clod-card field calibration test was performed in steady current flow of the discharge lagoon.

Apra Harbor tidal conditions during the survey period were taken from the NOAA, National Ocean Survey Tide Tables, Central and Western Pacific Ocean. Heights are reckoned from the datum, which is mean lower low water from soundings on charts of the area (NOAA Chart 81054, formerly C&GS 4197). See Table 3 for tidal conditions pertinent to the survey period.

DATA/RESULTS

The data and results for each specific sampling activity are presented in a sequence parallel to the description of methods provided in the previous section. The presentation format is designed to characterize those groups or assemblages of marine biota observed in the Piti intake environments. The selection of representative important species and a discussion of the intake effects they experience concludes this section.

Where biological samples were collected, voucher specimens or photographs are maintained at the Naval Ocean Systems Center, Hawaii Laboratory, Processing Center. All numerical and taxonomic data collected during this survey will be verified and entered into the Hawaiian Coastal Zone Data Bank for future reference, retrieval and manipulation.

Table 3. Tidal Conditions in the study area during the Piti Power Plant Intake Survey, November, 1977.

Guam (Apra Harbor), Mariana Islands, 1977
Times and Heights of High and Low Waters
All Times are Local

DAY	TIME	HEIGHT		DAY	TIME	HEIGHT	
		Feet	Meters			Feet	Meters
3	0552	0.3	0.1	10	0015	0.0	0.0
TH	1327	2.2	0.7	TH	0657	2.4	0.7
	1912	1.5	0.5		1230	1.0	0.3
	2337	1.8	0.5		1810	2.5	0.8
4	0646	0.4	0.1	11	0101	- 0.3	- 0.1
F	1416	2.2	0.7	F	0750	2.5	0.8
	2025	1.3	0.4		1316	1.1	0.3
					1847	2.5	0.8
5	0056	1.7	0.5				
SA	0743	0.5	0.2	12	0142	- 0.5	- 0.2
	1504	2.2	0.7	SA	0839	2.6	0.8
	2123	1.2	0.4		1406	1.2	0.4
					1927	2.6	0.8
6	0226	1.7	0.5				
SU	0848	0.6	0.2	13	0228	- 0.6	- 0.2
	1545	2.3	0.7	SU	0934	2.6	0.8
	2209	0.9	0.3		1457	1.3	0.4
					2009	2.5	0.8
7	0347	1.8	0.5				
M	0948	0.7	0.2	14	0317	- 0.6	- 0.2
	1624	2.3	0.7	M	1030	2.6	0.8
	2254	0.6	0.2		1552	1.4	0.4
					2057	2.4	0.7
8	0458	2.0	0.6				
TU	1046	0.8	0.2	15	0406	- 0.6	- 0.2
	1659	2.4	0.7	TU	1126	2.6	0.8
	2336	0.3	0.1		1652	1.4	0.4
					2146	2.3	0.7
9	0559	2.2	0.7				
W	1138	0.9	0.3				
	1733	2.4	0.7				

PLANKTON

Seventeen plankton tows were conducted during this survey (see methods section, this report, for a more detailed description of procedures used). The basic field data for zooplankton collections within the period 4–14 November, 1977, are summarized in Table 4. Laboratory analyses of these samples has provided distributional data for sixty-nine taxa (estimated to be greater than 100 species). A consolidated checklist (all samples and stations) has been assembled (see Appendix B). Numerical listings by taxa for each sampling region are shown in Tables 5–7.

Table 4. Plankton sampling field data summary, Piti Power Plant Intake Survey, November 1977.
Legend: PC=Piti Canal, ITC=Inner Tepungan Channel, OTC=Outer Tepungan Channel, OL=Outfall Lagoon, PO=Piti Outfalls #2 or #4 & #5.

Tow #	Area/Station	Time/Date	Vol. Water Filtered (m^3)	Tidal Conditions/Remarks
1	PC/9→7	1445/4 Nov	38.06	Hi tide @ 1416 (+0.7m); ebb
2	ITC/5→6	1400/5 Nov	51.38	Hi tide @ 1504 (+0.7m); flood
3	OTC/1→2	1451/5 Nov	41.76	"
4	PC/9→7	1539/5 Nov	35.46	" ; ebb
5	OTC/1→2	1135/7 Nov	48.38	Hi tide @ 1624 (+0.7m); flood
6	ITC/5→6	1201/7 Nov	44.19	"
7	PC/9→7	1237/7 Nov	48.31	"
8	OTC/1→2	1402/12 Nov	47.49	Low tide @ 1406 (+0.4m); slack
9	ITC/5→6	1428/12 Nov	43.64	" ; flood
10	PC/9→7	1501/12 Nov	40.31	" "
11	PC/9→7	1947/12 Nov	41.82	Hi tide @ 1927 (+0.8m); night
12	OTC/1→2	0912/14 Nov	50.14	Hi tide @ 1030 (+0.8m); flood
13	ITC/5→6	0935/14 Nov	44.08	"
14	PC/9→7	1008/14 Nov	39.85	"
15	OL/11	1045/14 Nov	47.24	" ; ebb
16	PO/10(4&5)	1110/14 Nov	34.36	" "
17	PO/10(2)	1135/14 Nov	22.82	" "

Note:
- All tows were 8 minutes in duration, surface (1 meter depth), using a 50cm diameter, 243μm mesh (Nitex) heavy duty construction net.
- Times listed are "start" times for each tow.
- Tows 1-15 were performed using a small outboard powered skiff at 1.5 knot speed.
- Tows 16 & 17 were taken by suspending the net in the outfall plume.

Table 5. Piti Canal Zooplankton Data (calc. #individuals/taxa).

	Sample Number					
	1	4	7	10	14	11
Pyrrophyta (Dinoflagellates)						
Ceratium sp.	0	0	0	0	0.60	0
Foraminifera						
Species A *?Tretomphalus*	30.4	36.4	65.2	32.5	29.6	23.0
Species B *?Calcarina*	0.10	3.0	2.2	0.57	0.20	0
Species C *?Triloculina*	0	0	0.17	0.02	0.70	0
Species D *?Amphisorus*	0	0.11	0	0	0	0
Rotifera	0	0	0	0	0	0
Cnidaria						
Siphonophora	0	0	0.04	0	0.30	0
Medusae	0.58	0.57	0.12	0.32	0.60	6.2
Nematoda	0	0	0	0	0.20	0
Annelida						
Polychaete larvae	0.74	0.57	1.1	0.05	1.4	1.0
Arthropoda/Crustacea						
Cladocera						
Evadne sp.	0	0.11	0	0.07	0	0
Ostracoda	0.21	0	0.33	0	0.40	18.2
Copepoda/Calanoida						
Acartia sp.	2.9	2.1	0.70	0.27	4.1	9.6
Acrocalanus spp.	0.21	0.11	0.08	0.05	0.60	0
Candacia sp.	0	0	0	0	0	0
Calanus sp.	0.16	1.0	0.08	0.02	0	0
Calocalanus sp.	0	0.11	0.08	0.05	0.20	0
Calocalanus pavo	0.05	0	0	0	0	0
Clausocalanus spp.	7.1	4.3	0.79	0.69	8.8	2.0
Centropages orsinii	0.74	0	0	0	1.8	422.0
Euchaeta sp.	0	0	0	0	0.10	0
"Gaetanus"-like sp.	0	0	0	0	0.10	0
Labidocera sp.	0	0.11	0	0	0.20	8.1
Lucicutia sp.	0	0	0.04	0	0.20	0
Mecynocera clausi	0.05	0.11	0.12	0	0.40	0
Paracalanus sp.	0.05	0.23	0.17	0	0.50	0
Pontellina sp.	0	0	0	0	0	0
Tortanus sp.	0	0	0	0	0	1.0
Undinula darwini	0.05	0	0	0	0	0.5
Undinula vulgaris	0	0	0	0	0	0
Undinula spp. (juvenile)	0.26	1.6	0	0	0	0
Unidentified calanoid (juvenile)	0	0	0	0	0	0.5
Calanoid nauplii larvae	0	0	0	0	0	0
Copepoda/Cylclopoida						
Corycaeus spp.	1.7	3.7	0.66	0.47	9.4	13.4
Lubbockia squillimana	0	0	0.04	0	0	0
Oithona plumifera	1.0	1.5	0.58	0.15	3.4	0
Oithona simplex	0	0	0	0.02	0	0
Oithona sp.	0	0	0	0	0	0
Oncaea sp.	0.74	0.79	1.0	0.17	1.2	0
Unidentified cyclopoids	0	0	0	0	0	0

Table 5. (Continued)

	Sample Number					
	1	4	7	10	14	11
Copepoda/Harpacticoida						
Metis sp.	0	0	0	0	0.10	0
Microsetella norvegica	0	0	0	0	0	0
Microsetella rosea	0	0	0.04	0.02	0	0
Porcellidium sp.	0.05	0	0	0	0	0
Zaus sp.	0.84	0	0.54	0.10	0.10	0
Unidentified harpacticoids	0.63	0.68	0.33	0.37	0.20	1.4
Copepoda/Monstrilloida	0	0	0	0	0	0
Copepoda/Caligoida	0	0.11	0	0	0.10	0
Arthropoda/Crustacea						
Cirripedia						
Nauplii A "small, slender"	0.05	1.8	0	0.37	0.40	1.9
Nauplii B "stout"	0	0.56	0.08	0.62	0	3.8
Cypris larvae	4.4	0.90	0.50	0.74	2.2	0.5
Malacostraca						
Cumacea	0	0	0.40	0	0	0
Isopoda	0	0.23	0	0.07	0.10	2.9
Amphipoda/Gammaridea	0.79	0.79	0.91	0.57	1.0	1.0
Decapoda/Shrimp mysis	0.58	0.57	0	0.07	0	418.0
Decapoda/Crab zoea	3.6	7.6	0.08	0.10	6.9	188.0
Decapoda/Crab megalops	0	0	0	0.02	1.4	1.9
Stomatopoda						
Stomatopod alima larvae	0	0	0	0.02	0	0
Mollusca						
Gastropoda						
Gastropod veliger larvae	0.32	1.4	4.6	0.82	2.2	6.7
Bivalvia						
Bivalve veliger larvae	0	0.11	0.41	0.02	0	0
Unidentified veliger larvae	0	0.11	0.33	0.05	1.4	1.0
Echinodermata						
Echinoderm larvae	0.15	0.45	0.08	0.07	0	0
Chaetognatha						
Sagitta enflata	0.05	0.34	0.12	0.02	0.60	0.5
Sagitta sp.	0.10	0.23	0	0	0.50	0.5
Chordata						
Urochordata						
Ascidacea						
Ascidian larvae	0	0	0	0	0	0
Larvacea						
Oikopleura sp.	0.32	0.34	0.75	0	0.90	0

Table 5. (Continued)

	Sample Number					
	1	4	7	10	14	11
Vertebrata						
Osteichthyes						
Fish larvae	0	0.11	0	0.07	0	17.2
Fish eggs "oval"	1.4	0.23	8.0	1.7	0.21	0
Fish eggs "round"	19.5	18.2	18.0	10.7	20.2	1.4
# individuals/cubic meter	79.82	91.22	108.67	51.94	103.51	1152.20
Settled Vol. (ml/cubic meter)	< .1	< .1	< .1	.05	< .1	0.5
Aliquots counted	1/4, 1/2	1/4	1/4, 1/2	All	1/4	1/40, 1/20

Table 6. Tepungan Channel Zooplankton Data (calc. #individuals/taxa).

	ITC		Sample Number				OTC	
	2	6	9	13	3	5	8	12
Pyrrophyta (Dinoflagellates)								
Ceratium sp.	0	0.09	0.18	0.72	0.19	0.04	0.08	0
Foraminifera								
Species A ?*Tretomphalus*	44.2	55.8	46.5	22.7	73.1	60.0	56.3	24.2
Species B ?*Calcarina*	0.47	0.18	0	2.0	5.7	0.08	0.04	1.3
Species C ?*Triloculina*	0	0.09	0	0.73	0.14	0.12	0	3.7
Species D ?*Amphisorus*	0	0	0	0	0.14	0	0	0
Rotifera	0	0	0	0	0	0	0	0
Cnidaria								
Siphonophora	0	0.14	0.18	0	0	0	0.17	0.08
Medusae	0.31	0.09	0.34	0.45	0.24	0.04	0.13	0.24
Nematoda	0	0.09	0	0.18	0	0.04	0.04	0
Annelida								
Polychaete larvae	0.39	1.4	0.25	1.8	0.86	0.62	0.04	0.24
Arthropoda/Crustacea								
Cladocera								
Evadne sp.	0	0	0.30	0	0	0	0.29	0
Ostracoda	0.47	0.14	0.09	0.82	0.14	0.12	0.04	0.24
Copepoda/Calanoida								
Acartia sp.	2.5	0.95	0.53	7.1	0.91	0.62	0.25	7.0
Acrocalanus spp.	0.70	0.27	0.30	0.91	0.14	0.21	0.25	0.48
Candacia sp.	0	0	0	0	0	0	0	0
Calanus sp.	0.08	0	0.05	1.8	0.05	0.95	0	0
Calocalanus sp.	0	0.14	0.18	0.81	0	0.04	0.29	0.24
Calocalanus pavo	0.08	0	0	0.18	0.10	0	0.13	0
Clausocalanus spp.	2.2	1.1	0.87	15.2	0.81	0.45	0.33	9.7
Centropages orsinii	0.08	0.09	0	0.82	0	0	0.08	0.64
Euchaeta sp.	0	0	0	0	0	0	0	0
"Gaetanus"-like sp.	0	0	0	0.64	0	0	0	4.4

Table 6. (Continued)

	ITC		Sample Number				OTC	
	0	6	9	13	3	5	8	12
Labidocera sp.	0.08	0.05	0	0.45	0	0	0	0.40
Lucicutia sp.	0	0	0	0.27	0	0	0	0.08
Mecynocera clausi	0	0.09	0.07	0.36	0	0	0	0.16
Paracalanus sp.	0.08	0.05	0.05	1.1	0.05	0	0.08	0.08
Pontellina sp.	0.08	0.05	0	0	0	0	0	0
Tortanus sp.	0	0	0	0.09	0	0	0	0
Undinula darwini	0	0	0	0.18	0	0	0	0.16
Undinula vulgaris	0	0	0	0	0	0	0	0
Undinula spp. (juvenile)	0.54	0.18	0	0	0.05	0.74	0	0.08
Unidentified calanoid juv.	0	0	0	0.09	0.05	0	0	0
Calanoid nauplii larvae	0	0.05	0.18	0	0	0	0.13	0
Copepoda/Cylclopoida								
Corycaeus spp.	5.1	1.6	1.2	18.9	1.2	0.95	1.0	1.1
Lubbockia squillimana	0	0.09	0	0.09	0	0.12	0	0
Oithona plumifera	0.46	0.45	0.34	4.9	0.48	0.70	0.17	5.0
Oithona simplex	0	0	0.05	0	0	0	0.04	0
Oithona sp.	0	0	0.02	0.09	0	0	0.04	0
Oncaea sp.	1.2	0.50	0.16	3.0	0.19	0.87	0.17	1.5
Unidentified cyclopoids	0	0	0	0	0	0	0	0
Copepoda/Harpacticoida								
Metis sp.	0	0	0.02	0	0	0	0	0
Microsetella norvegica	0	0.05	0	0.18	0	0	0	0
Microsetella rosea	0	0.05	0	0.63	0	0.04	0	0
Porcellidium	0	0	0.02	0.09	1.0	0	0.04	0.08
Zaus sp.	0.86	1.6	0.16	0	0	0	0.08	0
Unidentified harpacticoids	0.16	0.59	0.07	0.09	1.2	0	0.08	0.08
Copepoda/Monstrilloida	0	0	0	0	0.10	0.04	0	0
Copepoda/Caligoida	0	0	0	0	0.10	0	0	0
Arthropoda/Crustacea								
Cirripedia								
Nauplii A "small, slender"	0.08	0.18	12.5	0.64	0.62	0.21	3.7	1.0
Nauplii B "stout"	0	0	0	0	0.09	0	0	0.16
Cypris larvae	2.1	0.59	1.0	3.7	2.3	0.87	0.25	1.8
Malacostraca								
Cumacea	0	0	0	0	0	0	0	0
Isopoda	0	0	0.07	0.18	0.19	0	0	0.08
Amphipoda/Gammaridea	0.86	0.59	0.89	0.54	0.86	0.41	0.08	0.16
Decapoda/Shrimp mysis	0.08	0.09	0.16	1.9	0.47	0.04	0	0.32
Decapoda/Crab zoea	0.31	0.18	0.73	3.1	2.1	0.04	0.37	2.0
Decapoda/Crab megalops	0	0	0	0.09	0	0	0	0
Stomatopoda								
Stomatopod alima larvae	0	0	0	0	0	0	0	0
Mollusca								
Gastropoda								
Gastropod veliger larvae	0.16	1.2	0.09	3.6	0.48	0.41	0.17	2.6
Bivalvia								
Bivalve veliger larvae	0	0	0	0.64	0	0	0	0

Table 6. (Continued)

	ITC		Sample Number				OTC	
	0	6	9	13	3	5	8	12
Unidentified veliger larvae	0	0	0.02	0.27	0	0	0.04	0
Echinodermata								
Echinoderm larvae	0.08	0.05	0	0.09	0.29	0	0	0
Chaetognatha								
Sagitta enflata	1.1	0.05	0.11	1.6	0.81	0.04	0.34	1.9
Sagitta sp.	0.86	0.14	0.41	0	0.10	0.29	0	0.40
Chordata								
Urochordata								
Ascidacea								
Ascidian larvae	0	0	0	0	0	0	0	0
Larvacea								
Oikopleura sp.	1.8	2.2	0.11	0.90	0.52	5.5	0.04	1.7
Vertebrata								
Osteichthyes								
Fish larvae	0.16	0	0.05	0.27	0.10	0.04	0.04	0.24
Fish eggs "oval"	1.6	1.0	2.2	2.7	0.29	0.08	2.0	0.08
Fish eggs "round"	14.9	12.0	15.2	15.2	26.0	7.5	12.4	4.8
# individuals/cubic meter	84.13	84.24	85.65	122.79	122.16	82.22	79.72	78.42
Settled Vol.(ml/cubic meter)	<.1	<.1	<.1	<.1	<.1	<.1	<.1	<.1
Aliquots counted	¼	¼,½	All	¼,½	¼,½	¼,½	¼,½	¼

Table 7. Outfall Lagoon Zooplankton Data (#individuals/taxa).

		Sample Number	
	15	16	17
Pyrrophyta (Dinoflagellates)			
Ceratium sp.	0	0	0
Foraminifera			
Species A *?Tretomphalus*	2.9	28.4	15.3
Species B *?Calcarina*	0	0.93	2.5
Species C *?Triloculina*	0.36	0.58	0.44
Species D *?Amphisorus*	0	0	0

Table 7. (Continued)

	Sample Number		
	15	16	17
Rotifera	0	0	0.04
Cnidaria			
Siphonophora	0	0	0
Medusae	0.23	0.14	0
Nematoda	0.04	0.09	0
Annelida			
Polychaete larvae	0.08	0.61	0.74
Arthropoda/Crustacea			
Cladocera			
Evadne sp.	0	0	0
Ostracoda	0.04	0.37	0.31
Copepoda/Calanoida			
Acartia sp.	0.28	0.73	0.74
Acrocalanus spp.	0.17	0.09	0.04
Candacia sp.	0	0.03	0
Calanus sp.	0	0.06	0.09
Calocalanus sp.	0	0.03	0
Calocalanus pavo	0	0.03	0
Clausocalanus spp.	0.15	1.6	1.6
Centropages orsinii	0.51	0.20	0.74
Euchaeta sp.	0	0	0
"Gaetanus"-like sp.	0	0	0
Labidocera sp.	0.80	0.23	0.13
Lucicutia sp.	0	0.03	0
Mecynocera clausi	0.02	0.03	0.04
Paracalanus sp.	0.08	0.09	0.13
Pontellina sp.	0.02	0	0
Tortanus sp.	0	0.03	0
Undinula darwini	0	0.09	0
Undinula vulgaris	0.34	0.03	0
Undinula spp. (juvenile)	0	0	0.09
Unidentified calanoid juv.	0	0	0
Calanoid nauplii larvae	0	0	0
Copepoda/Cylclopoida			
Corycaeus spp.	0.53	1.7	1.5
Lubbockia squillimana	0	0	0
Oithona plumifera	0.11	0.26	0.35
Oithona simplex	0.11	0	0
Oithona sp.	0	0	0
Oncaea sp.	0.17	0.35	0.48
Unidentified cyclopoids	0.02	0	0

Table 7. (Continued)

	Sample Number 15	16	17
Copepoda/Harpacticoida			
Metis sp.	0	0.03	0.04
Microsetella norvegica	0	0	0
Microsetella rosea	0	0	0
Porcellidium sp.	0	0.09	0.09
Zaus sp.	0	0.09	0.13
Unidentified harpacticoids	0	0.32	0.39
Copepoda/Monstrilloida	0	0	0
Copepoda/Caligoida	0.04	0	0
Arthropoda/Crustacea			
Cirripedia			
Nauplii A "small, slender"	0	0.17	0.13
Nauplii B "stout"	0.08	0	0.04
Cypris larvae	0.76	1.2	1.2
Malacostraca			
Cumacea	0	0.06	0
Isopoda	0	0.15	0.22
Amphipoda/Gammaridea	0.02	0.38	0.22
Decapoda/Shrimp mysis	1.8	0.55	0.88
Decapoda/Crab zoea	3.1	2.0	2.5
Decapoda/Crab megalops	0.02	0	0
Stomatopoda			
Stomatopod alima larvae	0	0	0
Mollusca			
Gastropoda			
Gastropod veliger larvae	0.70	2.4	2.1
Bivalvia			
Bivalve veliger larvae	0	0.23	0.52
Unidentified veliger larvae	0.08	0.09	0.31
Echinodermata			
Echinoderm larvae	0	0	0
Chaetognatha			
Sagitta enflata	0.02	0.06	0.04
Sagitta sp.	0	0.06	0

Table 7. (Continued)

	Sample Number 15	16	17
Chordata			
Urochordata			
Ascidacea			
Ascidian larvae	0	0	0.09
Larvacea			
Oilopleura sp.	0	0	0
Vertebrata			
Osteichthyes			
Fish larvae	0.12	0.06	0.13
Fish eggs "oval"	0	0	0.09
Fish eggs "round"	1.5	9.3	6.4
# individuals/cubic meter	15.20	53.97	40.78
Settled Vol. (ml/cubic meter)	<.1	<.1	0.09
Aliquots counted	All	All	All

Data collected during six separate zooplankton tows in Piti Canal (see Figure 2) are listed in Table 5. The numerically abundant forms (e.g., 3–50+ individuals/taxon/cubic meter) present in Piti Canal during daytime collections include: the foraminerans, *?*Tretomphalus* & ?*Calcarina;* calanoid copepods, *Acartia* & *Clausocalanus* (several species); cyclopoid copepods, *Corycaeus* & *Oithona plumi era* Baird; barnacle cyprid larvae; crab zoea; gastropod veliger larvae and fish eggs. A single nighttime zooplankton tow was performed in Piti Canal during the evening of 12 November 1977 at high tidal conditions. This sample contained a dense concentration of zooplankton, i.e., 1152 individuals per cubic meter.

The calanoid copepod, *Centropages orsinii* (Giesbrecht) and shrimp mysis larvae were especially abundant, i.e., more than 400 individuals per cubic meter. Other numerically significant forms present in this sample include: medusae, ostracods, *Acartia, Labiodocera, Corycaeus* (several species), barnacle nauplii (type B, "stout"), isopods, gastropod veliger larvae and larval fishes (several families). Several recent studies (Alldredge and King, 1977; Porter and Porter, 1977a and 1977b; Glynn, 1973) have documented a greater abundance of demersal plankton in coral reef habitats during night hours, especially near dawn and dusk periods. The increased abundance of zooplankton in this nighttime sample are probably due to a combination of environmental factors in addition to the condition of darkness. The influence of tropical storm Kim four days prior to this collection provided substantial rainfall with attendant nutrient inputs via terrestrial runoff to nearshore marine environments in the

* See page 6.

study area. Additionally, on 12 November "new" moon and spring tide conditions were present. Several authors (Dew and Wood, 1955; Barnes, 1962; Crisp, 1974; Straughan, 1969 and 1972) have observed a positive correlation between the fortnightly spring tide conditions and larval availability and settlement patterns in many meroplanktonic forms. Increased numerical abundance in daytime tows on 14 November in other intake regions further supports the above discussion. Fifty-seven taxa were present in five daytime zooplankton tows taken in Piti Canal. The calculated mean number of individuals per cubic meter from pooled sample data was 86.73 (standard deviation: 22.35). Twenty-seven taxa were present in the single nighttime tow from Piti Canal.

Data collected during eight different zooplankton tows in Tepungan Channel (for reference location, refer to Figure 2) are presented in Table 6. Four tows were conducted in each region, Inner Tepungan Channel (Station 5→6) and Outer Tepungan Channel (Station 1→2. Faunal composition and relative abundances from these two areas are similar. Some minor singularities do exist, however, for rarer forms such as *?Amphisorus, Tortanus* and *Metis*. Numerically abundant forms present in Tepungan Channel daytime tows include: the foraminiferans, *?Tretomphalus, Calcarina* and *?Triloculina*; calanoid copepods, *Acartia* and *Clausocalanus* (several species); cyclopoid copepods, *Corycaeus* and *Oithona plumifera* Baird; barnacle nauplii (type A "small, slender") and barnacle cyrids; crab zoea; gastropod veliger larvae; the larvacean, *Oikopleura* and fish eggs. No nighttime tows were conducted in Tepungan Channel. The calculated mean number of individuals per cubic meter from pooled sample data was 94.20 (standard deviation: 19.07) for Inner Tepungan Channel and 90.61 (standard deviation: 21:03) for Outer Tepungan Channel.

Three separate zooplankton tows were taken in the region of the Piti outfall lagoon on 14 November 1977 (samples #15 – #17). Fifty-one taxa were present in these samples. Numerically abundant forms in the outfall lagoon were: the foraminiferan, *Tretomphalus*, crab zoea and fish eggs. Overall abundance of individuals as lower in the outfall lagoon than in the intake environments. The outfall lagoon, a more estuarine environment, was expected to support a different zooplankton community. Rotifers, ascidian larvae, the calanoid copepod, *Undinula vulgaris* (Dana) and an unidentified cyclopoid copepod were found only in the discharge lagoon collections. A dinoflagellate, *Ceratium*, echinoderm larvae and the larvacean, *Oikopleura*, were absent in the outfall lagoon, whereas these groups were commonly collected from intake areas. However, the composition of the outfall lagoon community does include forty-four taxa common to the intake areas. Calculated mean number of individuals per cubic meter from pooled sample data was 36.65 (standard deviation 19.71) for the three outfall zooplankton collections (see Table 7).

A comparison of zooplankton abundance statistics for each study region (i.e., Piti Canal, Tepungan Channel and the Outfall Lagoon) is summarized in Table 8. ANOVA and "t" test of means have been computed for abundance data (number of individuals per cubic meter) from pooled samples. Sample variances, when compared with each other by F-test are not significantly different. However, the mean abundance of zooplankton collected from the outfall lagoon region is significantly lower ($P<0.005$) than from intake areas. Differences in community composition (estuarine vs. open coastal), the "stationary" tow collection technique for two of the outfall samples, and mortality from entrainment of certain zooplankters, especially larger forms, are possible explanations for these differences.

Table 8. Comparison of pooled sample statistics for each zooplankton sampling region, Piti Power Plant Intake Survey, November 1977.

Area	n	$\overline{X}$	s
Piti Canal (PC)	5	87.03	22.59
Inner Tepungan Ch. (ITC)	4	94.20	19.04
Outer Tepungan Ch. (OTC)	4	90.63	21.08
Outfall Lagoon (OL)	3	36.65	19.71

ANOVA & "t" test of means (Snedecor & Cochran, 1967, sections 10.7 & 10.12)

Source	degrees of freedom	sum of squares	mean square	F
between	3	7142.51	2380.84	5.45*
within	12	5241.95	436.83	
total	15	12384.46		

Comparisons:

intake (PC, ITC & OTC) vs OL = 4.02** df = 12

PC vs ITC & OTC = –0.45 N. S.

ITC vs OTC = 0.24 N. S.

N. S. = not significant
* = significant at $P < 0.05$ level.
** = significant at $P < 0.005$ level.

The percent mortality of entrained biota was not specifically evaluated during this study, however, since two samples (#16 and #17) were collected directly from the discharge plumes and many live zooplankton were observed in these samples, considerably less than 100% entrainment mortality probably occurs at the Piti Plant.

Characteristically common fauna present in zooplankton samples are shown in Figure 7. The mean plankton composition of each study region is presented as percent of pooled samples. Foraminiferans composed 51% of the total zooplankton abundance collected during daylight hours. Copepods and fish larvae each represented an additional 18% of the total mean daytime abundance of zooplankton. Other meroplanktonic taxa such as barnacle larvae, crab zoea and gastropod veligers represented 4%, 2% and 2%, respectively. Nighttime

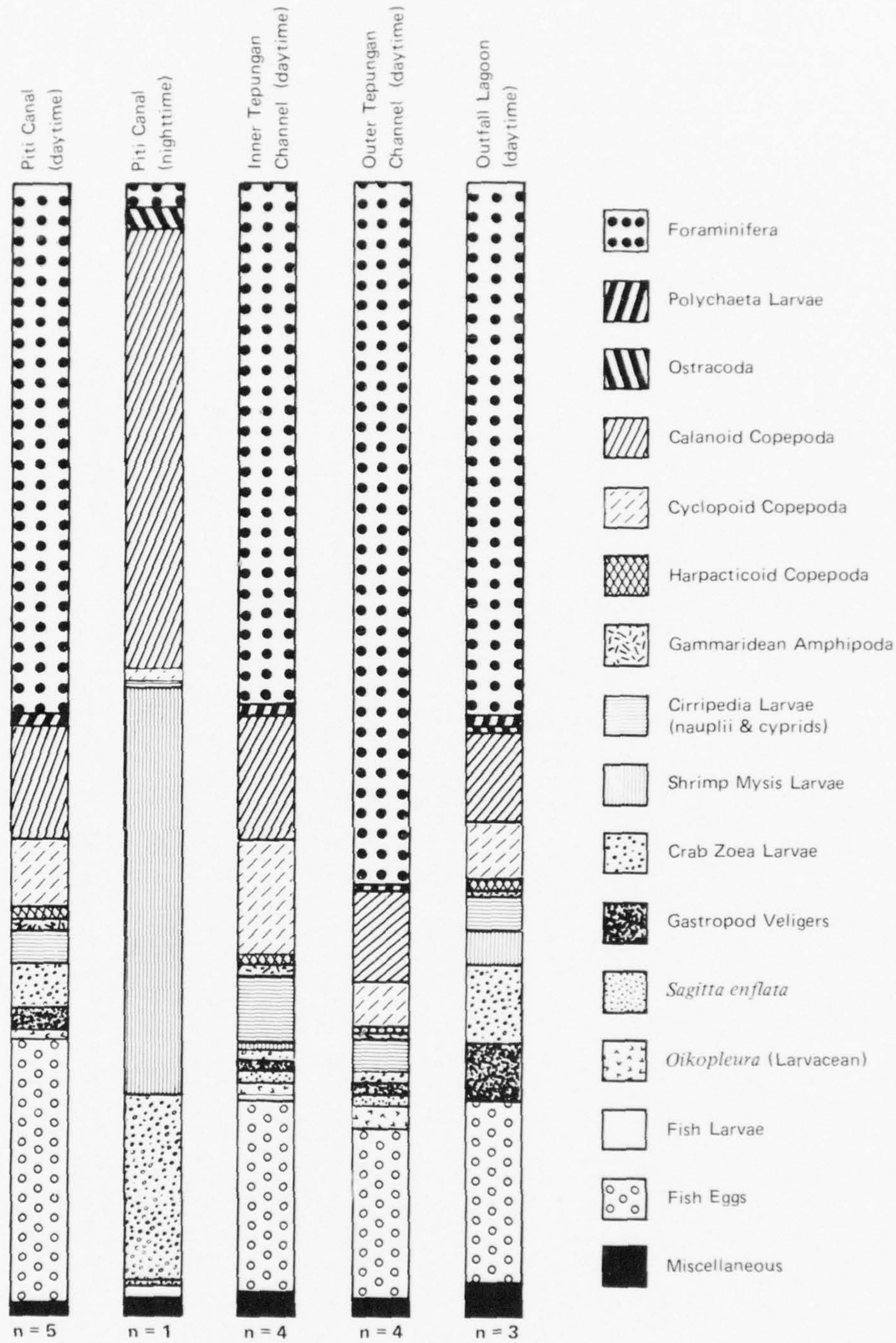

Figure 7. Histogram comparing proportional abundance (by mean number of individuals/taxa/region) of fifteen groups of zooplankton, Piti Power Plant Intake Survey, November, 1977.

data are considerably different, as indicated by the single collection from Piti canal. Here, foraminiferans represented only 2% of the total collection, while calanoid copepods and shrimp mysis composed 39% and 36%, respectively. Crab zoea represented 16% of this nighttime collection.

Meroplankton, those planktonic life stages (often larvae or eggs) of fishes and macroinvertebrates which reside as plankton during part of their life cycle, are an important component of the plankton assemblages. A listing of the relative abundance of meroplanktonic forms present in samples from the Piti study regions is shown in Table 9.

Table 9. Relative abundance of meroplankton present in zooplankton samples, Piti Power Plant Intake Survey, November, 1977.

Legend: R = Rare (present in 1–2 samples); P = Present (3–7 samples); C = (8–12 samples); V = Very common (12–17 samples).

Taxa/Group			Frequency
Ascidian Larvae			R
Cirripedia Larvae	Nauplii (type A "small, slender")		V
	Nauplii (type B "stout")		C
	Cypris		V
Decapod Larvae	Shrimp mysis		V
	Crab Larvae	Zoea	V
		Megalops	P
Echinoderm Larvae			C
Fish Eggs	Oval		V
	Round		V
Fish Larvae			V
Molluscan Larvae	Gastropod veligers		V
	Bivalve veligers		P
Polychaete Larvae			V
Stomatopod alima Larvae			R
Unidentified Veliger Larvae			C

Generally, the zooplankton data obtained during this study are representative of a moderately productive inshore coral reef environment when compared with data from other studies (Doty and Marsh, 1977; Amesbury *et al.*, 1975; Glynn, 1973; Emery, 1968; Wickstead, 1961). Adverse effects attributable to entrainment of zooplankton (including larval fishes and fish eggs) are probably low due to the large recruitment reservoir for planktonic biota from the extensive nearshore coral reef areas on the Philippine Sea side of Guam.

IMPINGEMENT

Observations and collections made during the survey indicate that faunal impingement is very low at the Piti Power Plant intake structures. Data collected for six different sampling periods are summarized in Table 10. Drift algae and seagrass constitute the major portion of

Table 10. A summary of Impingement Collections and Observations made during the Piti Power Plant Intake Survey, November, 1977.

Legend: R = Rare (present in one collection); P = Present (2–4); C = Common present in all collections).

Taxa	Frequency
Algae	
Sargassum polycystum	C
Padina tenuis	P
Dictyota bartayresii	P
Polysiphonia tepida	R
Seagrass	
Enhalus acoroides	C
Foraminifera	
several species	P
Cnidaria	
Dynamena crisioides	P
Hebella sp.	P
Cassiopea andromeda	R
Mollusca	
Nerita plicata	P
Trochus niloticus	P
Echinodermata	
Diadema setosum	R
Echinometra mathei	P
Holothuria cinerascens	R
Opheodesoma grisea	R
Fish	
Canthigaster solandri	R

biomass retained on the traveling screens and bar grates. For a period of several days after tropical storm Kim had passed over Guam on 8 November 1977, increased amounts of drift algae and seagrass as well as terrestrial debris were observed during impingement collections.

While rates of impingement were observed to be very low, collections at the intakes for Piti Units #4 and #5 provided about three times the biomass as compared with collections at Piti Units #2 and #3 intakes. Cooling water circulating pumps are considerably larger capacity for units #4 and #5, 42,500 GPM each for pumps as compared with two, 10,000 GPM circulating pumps for units #2 and #3. Intake velocities at the traveling screens for units #4 and #5 were estimated at a mean value of 30–60 cm/sec (1–2 ft/sec). Station 9 (see Figure 2) was located along the eastern shoreline of Piti Canal for the intakes to unit #2 and within 50 meters of the traveling screens for units #4 and #5. Integrated water motion data (using clod-cards) over a six-day period at this station measured water motion at 8.40 cm/sec. The dimensions of the immediate intake structures as the Piti Plant are sufficiently large to minimize impingement effects of high flow volume on free-swimming marine biota. The overall impact of impingement at the Piti Plant is considered minimal.

NEKTON

The fish fauna of Piti intake environments is both diverse and abundant. A cumulative checklist has been assembled from transect data, observations and photographs (see Appendix C) which lists sixty-five species from thirty-two families of fishes. Families, genera and species are listed alphabetically and naming authorities have also been included after verification with the Checklist of Guam Fishes (Kami, *et al.*, 1968, 1971, and 1975). No new species records were obtained for fishes identified during this survey.

Three fish transect stations were selected at the beginning of this survey (see Figure 2 for locations) in Piti Canal, Inner Tepungan Channel and Outer Tepungan Channel. Along each of these twenty meter transects all fish species were identified, enumerated and a mean standard length (cm) was estimated for each species. Figure 8 depicts vertical profiles and illustrates pertinent physical features for each transect location. Data collected during the fish transecting activities are shown in Table 11.

The data from observations of nektonic forms collected during this survey generally agree with visual counts made in May 1972, by Jones and Larson (Marsh and Gordon, 1972). Even though Piti Canal and parts of Tepungan Channel have been constructed or extensively modified by human activities, the resident fish fauna is provided with sufficient substrate variety to support a diverse assemblage of forms. No significant adverse impact from the Piti intake structures was apparent for nektonic organisms during the survey.

BENTHIC BIOTA

Observations and collections of benthic organisms have provided data for more than 125 species (see Checklist, Appendix D) for the Piti intake environments. Sampling stations used for fish transects were also utilized for quantitative benthos transect and quadrat sampling (See Figure 2). Table 12 lists macroinvertebrates observed along three twenty-meter transects. The long-spined urchin, *Diadema setosum* was very common in most intake areas. Invertebrate distribution was highly related to substrate conditions. Vertical profiles are depicted for each transect station in Figure 8.

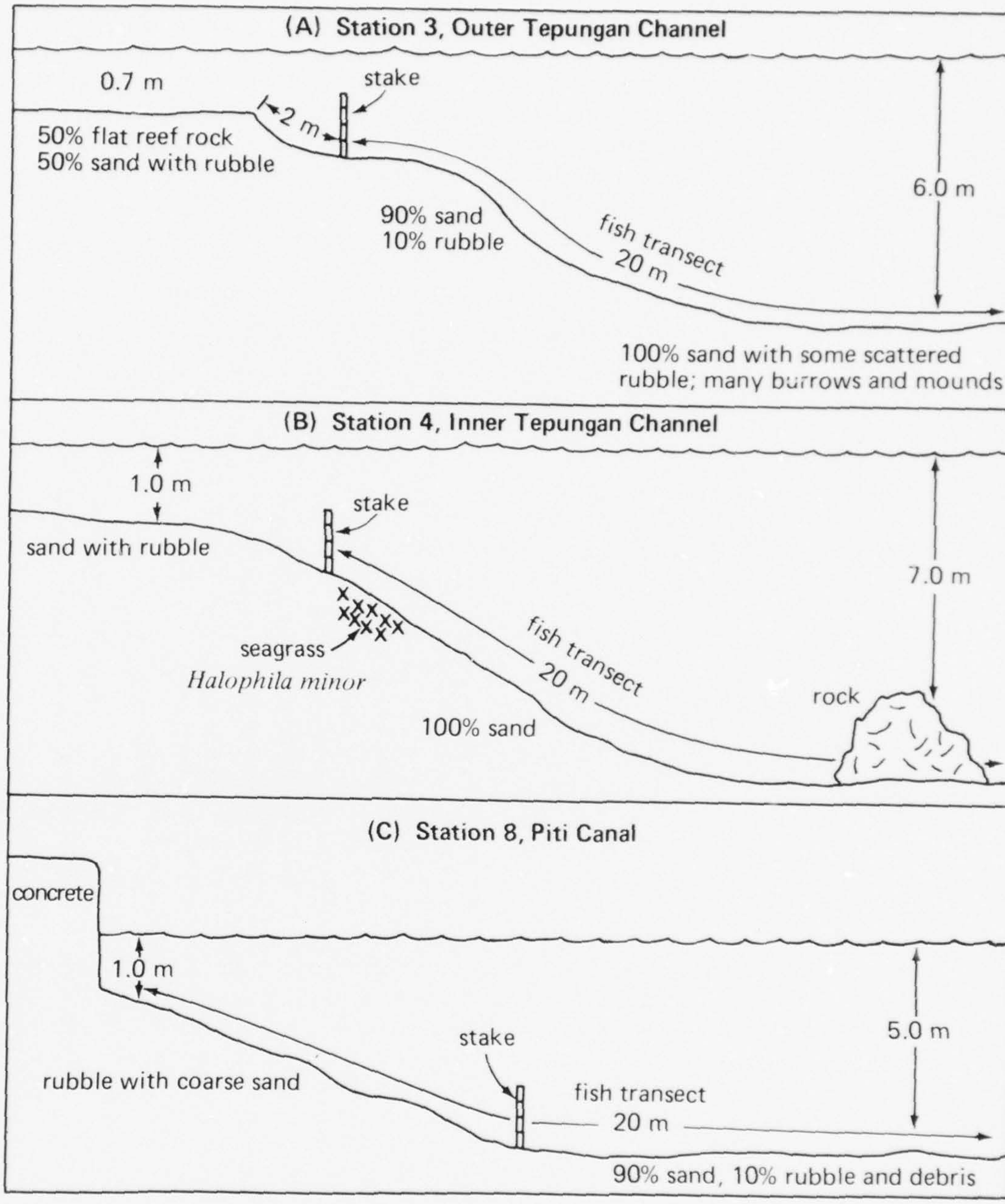

Figure 8. Vertical profiles at three transect stations, Piti survey.

Table 11. Fish Transect Data Collected at Three Stations during the Piti Power Plant Intake Survey, November, 1977.

	Species	# individuals	Estimated mean length (cm)
Sta. 3 Outer Tepungan Channel	*Bothus* sp.	1	20
	Canthigaster bennetti	4	6
	Canthigaster solandri	1	6
	Dascyllus aruanus	1	6
	Echidna nebulosa	2	35
	Eleotridae	2	7
	Eupomacentrus nigricans	1	8
	Gobiidae	> 50	5
	Naso literatus	1	15
	Paramia quinquelineata	2	8
	Pomacentridae	1	6
	Rhinecanthus aculeatus	2	9
	Stethojulis bandanensis	6	8
Sta. 4 Inner Tepungan Channel	*Apogon novemfasciatus*	10	9
	Canthigaster benneti	1	7
	Canthigaster solandri	3	6
	Chelon vaigensis	> 200	20
	Eleotridae (*Asteropteryx*)	> 25	6
	Eupomacentrus nigricans	2	8
	Gobiidae	> 50	6
	Paramia quinquelineata	8	10
	Parupeneus barberinus	3	18
	Pomacentrus pavo	6	8
	Rhinecanthus aculeatus	2	7
	Stethojulis bandanensis	5	9
Sta. 8 Piti Canal	*Apogon novemfasciatus*	5	10
	Aulostomus chinensis	1	30
	Canthigaster solandri	5	6
	Chelio inermis	1	17
	Halichoeres trimaculatus	1	12
	Paramia quinquelineata	8	8
	Pomacentrus pavo	1	7
	Note: Gobiidae conspicuously absent.		

Table 12. Macroinvertebrate transects performed during the Piti Power Plant Intake Survey, November, 1977.

Taxa	Station 3	Station 4	Station 8
Algae			
Cladophora sp.	–	~ 50 clumps	–
Halimeda macroloba	~ 20 clumps	–	–
Crustacea			
Alpheus pacificus	1	–	–
Dardanus sp.	> 50	> 50	> 50
Stenopus hispidus	–	–	2
Corals			
Acropora sp.	–	1 colony	1 colony
Pocillopora damicornis	–	30	7
Porites lutea	–	1	–
Echinoderms			
Diadema setosum	2	8	32
Echinometra mathei	1	1	–
Toxopneustes pileolus	–	–	1
Bohadschia argus	1	–	–
Holothuria cinerascens	1	–	–
Opheodesoma grisea	1	–	–
Mollusks			
Conus ebraeus	1	–	–
Cyprea moneta	3	–	–
Strombus luhuanus	10	–	–
Pinna muricata	–	1	–
Polychaetes			
Sabellastarte indica	–	8	3

Square meter quadrat sampling provided a quantitative measure of percent cover and density of macrobiota along the three transect stations. These data are tabulated in Table 13. As reported by Marsh (1977) the reef flat environment supports a diverse biota; however, the slope and channel bottom areas are relatively unstable environments which support only a few specialized forms. The unidentified shrimp-goby association mentioned by Marsh was observed during field sampling; however, repeated attempts to collect specimens for identification were unsuccessful.

Table 13. Percent coverage data for quadrat samples at three locations during the Piti Power Plant Intake Study, November, 1977.

(A) Station 3, Outer Tepungan Channel.

	Reef Flat			Slope			Bottom		
Taxa	3m	6m	9m	2m	4m	6m	9m	12m	15m
Algae									
Caulerpa serrulata	8	2	–	–	–	–	–	–	–
Dictyota bartayresii	30	66	25	10	25	28	3	12	2
Halimeda macroloba	3	3	–	–	–	6	5	3	4
Hormothamnion enter.	–	4	8	–	6	20	–	–	–
Lobophora variegata	–	–	5	–	–	–	–	–	–
Microcoleus lyngby.	–	–	–	–	–	–	–	8	–
Neomeris annulata	–	–	–	–	3	5	8	4	–
Padina tenuis	96	92	98	8	9	8	–	4	–
Polysiphonia tepida	–	1	–	11	8	32	–	10	3
Schizothrix calcicola	–	2	2	–	–	5	–	–	–
Porifera									
unident. grn & blk.	–	–	3	–	–	–	–	–	–
Crustacea									
unident. red burrowing shrimp (Homaridae?)	7	5	2	2	6	4	–	–	–
Mollusca									
Conus ebraeus	–	3	–	–	–	–	–	–	–
Strombus luhuanus	–	5	–	–	–	–	–	–	–
Fish									
Rhinecanthus (in burrow)	–	1	–	–	–	–	–	–	–
(B) Station 4, Inner Tepungan Channel.									
Algae									
Cladophora sp.	8	18	–	–	–	–	–	–	–
Dictyota bartayresii	10	3	2	–	–	–	–	–	–
Enteromorpha clathrata	17	20	22	–	–	–	–	–	–
Halimeda opuntia	2	–	–	–	–	–	–	–	–
Neomeris annulata	5	3	5	–	–	–	–	–	–
Padina tenuis	54	42	28	–	–	–	–	–	–
Polysiphonia tepida	–	13	6	–	–	–	–	–	–
Corals									
Acropora	1	–	–	–	–	–	–	–	–
Pocillopora damicornis	5	–	2	–	–	–	–	–	–
Sinularia polydactyla	–	–	–	–	1	–	–	–	–

Table 13. (Continued)

Taxa	Reef Flat 3m	Reef Flat 6m	Reef Flat 9m	Slope 2m	Slope 4m	Slope 6m	Bottom 9m	Bottom 12m	Bottom 15m
Crustacea									
unident. red burrowing shrimp (Homaridae?)	3	5	8	–	–	–	–	–	–
Sand Mounds	–	–	4	3	–	–	3	2	–

(C) Station 8, Piti Canal.

	Slope 1m	Slope 3m	Slope 5m	Bottom 9m	Bottom 12m	Bottom 15m
Algae						
Dictyota bartayresii	–	–	–	–	–	3
Halimeda macroloba	–	–	–	–	–	16
Echinoderms						
Diadema setosum	4	–	7	–	–	–
Holothuria cinerascens	1	–	–	–	–	–

Three fouling panel arrays were exposed for twelve days during the survey. Locations for these arrays are shown in Figure 2. One additional array was exposed in the outfall lagoon for comparison with intake epibiota. During this exposure only light amounts of algal fouling was observed. No macrofaunal settlement was apparent other than tube-dwelling amphipods collected from the array at Station 9. Table 14 lists the algal species identified from panel scrapings. Tsuda and Kami (1973) investigated algal fouling and succession on artificial (tire) reefs off Merizo, southern Guam and found little seasonality by algae during sixteen months of observation. It is probable that low initial fouling rates exist throughout the Piti intake environments. Evidence of moderate to heavy grazing by herbivorous fishes, echinoids and molluscs was observed on panels from Station 7 in Piti Canal.

WATER QUALITY

Physical and chemical parameters measured during the survey indicate that biota inhabiting the Piti intake environments experience a relatively narrow range of water quality conditions. A summary of these data is shown in Table 15. The nutrient values for NO_3-N, NH_4-N and PO_4-P are somewhat higher than anticipated and should be viewed with caution. The elevated nutrient values observed for samples collected on 12 and 14 November may represent an effect of tropical storm Kim; however, the pattern is unclear. Temperature data show effects of solar insolation in shallow areas during midday sampling. Marsh (1977) discusses problems associated with defining "ambient" temperatures in the Piti–Cabras area. Salinities are near-oceanic; however, a slight dilution effect of heavy rainfall on 8 November is

Table 14. Algal species identified from fouling panels exposed at four locations during the Piti Power Plant Intake Survey, November, 1977. (Percent composition estimates are given for major taxa); X = present.

Taxa	Sta 5	Sta 7	Sta 9	Sta 11
Cyanophyta:		5%	1%	
Oscillatoriaceae		X	X	
Chlorophyta:	100%			
Bornatella sp.	X			
Chrysophyta:		35%	2%	
Coscinodiscus sp.		X		
Grammotophora sp.		X		
Licomorpha sp.		X	X	
Navicula sp.		X	X	
Nitzschia sp.		X		
Stictocyclus sp.			X	
Phaeophyta:		60%	95%	100%
Ectocarpus sp.		X	X	X
Rhodophyta:			2%	
Gelidiella sp.			X	

Table 15. Summary of water quality measurements made during Piti Power Plant Intake Survey, November, 1977.

Station	Depth(m)	Date	Time	Temp.	Sal.	D.O.	NO_3	NH_4	PO_4
1	0.5	5 Nov	1450	30.4	-	9.4	6.0	0	7.0
	1.0					9.8			
3	0.5	"	1500	30.5	-	8.5	0	0	0
	1.0					8.7			
4	0.5	"	1510	29.4	-	7.8	2.2	5.0	7.0
	1.0					8.1			
7	0.5	"	1610	29.8	-	8.4	4.9	7.5	14.0
	1.0					9.3			
8	0.5	"	1525	29.4	-	8.0	7.7	0	18.0
	1.0					8.6			
9	0.5	"	1640	30.5	-	8.3	1.6	0	42.0
	1.0					8.7			
11	0.5	"	1700	32.1	-	7.7	0.5	0	0
	1.0					8.3			

Table 15. (continued)

Station	Depth(m)	Date	Time	Temp.	Sal.	D.O.	NO_3	NH_4	PO_4
1	0.5	7 Nov	1130	29.7	34.8	9.1	0	0	0
	1.0			29.7		9.35			
	2.0			29.7		10.1			
3	0.5	"	1150	30.0	34.8	8.1	1.1	0	7.0
	1.0			30.2		9.5			
4	0.5	"	1215	30.0	34.8	7.5	2.7	12.5	20.0
	1.0					8.9			
5	0.5	"	1158	30.5	34.8	8.15	1.6	17.5	22.0
	1.0			30.5		8.6			
	2.0			30.5		10.15			
7	0.5	"	1230	30.2	34.8	7.8	0	0	16.0
	1.0			30.2		7.9			
8	0.5	"	1245	30.5	34.8	7.3	1.6	0	7.0
	1.0			30.5		8.9			
9	0.5	"	1300	30.7	34.8	7.8	0	0	0
	1.0			30.7		8.6			
11	0.5	"	1310	32.8	34.1	7.0	1.6	0	0
1	0.5	12 Nov	1415	29.5	34.5	8.0	0	0	5.0
	1.0			29.5		7.9			
	2.0			29.5		8.5			
3	0.5	"	1430	29.7	34.5	9.0	0	0	18.0
	1.0			29.5		8.8			
	2.0			29.5		9.2			
4	0.5	"	1445	29.8	34.0	9.6	0	75.0	34.0
	1.0			29.4		9.8			
5	0.5	"	1440	29.8	34.2	9.6	3.3	20.0	26.0
	1.0			29.8		9.6			
	2.0			29.8		9.1			
7	0.5	"	1505	28.6	34.5	7.0	16.5	75.0	39.0
	1.0			28.6		6.9			
8	0.5	"	1455	29.4	34.4	8.9	2.2	10.0	29.0
	1.0			29.4		8.8			
9	0.5	"	1530	29.4	34.4	8.35	10.4	52.5	33.0
	1.0			29.4		8.55			
11	0.5	"	1540	32.7	34.2	7.3	7.7	30.0	26.0
	1.0			32.7		7.2			
1	0.5	14 Nov	0910	27.6	-	6.2	0.5	3.0	14.0
	1.0			27.6		6.35			
	2.0			27.8		6.85			
3	0.5	"	0923	27.7	-	6.9	0	5.0	18.0
	1.0			27.7		7.4			
4	0.5	"	0945	27.9	-	6.55	3.3	0	20.0
	1.0			27.9		6.45			
5	0.5	"	0934	27.3	-	6.25	0	25.0	14.0
	1.0			27.5		6.15			
	2.0			27.5		6.7			

Table 15. (continued)

Station	Depth(m)	Date	Time	Temp.	Sal.	D.O.	NO_3	NH_4	PO_4
7	0.5	"	1020	28.0	–	7.1	6.5	5.0	42.0
	1.0			28.0		7.0			
8	0.5	"	1005	28.0	–	7.2	3.3	10.0	20.0
	1.0			28.0		7.1			
9	0.5	"	1040	27.8	–	7.25	4.4	0	39.0
	1.0			27.8		7.35			
11	0.5	"	1050	29.2	–	6.6	0.8	2.5	37.0
	1.0			29.0		6.6			

weakly apparent in samples collected on 12 November. Dissolved oxygen values are well within the tolerance of marine biota in the study areas. The data for Tepungan Channel stations show the effects of oxygen production by reef flat algae during midday periods.

Data collected using maximum and minimum thermometers is shown in Table 16. Again these data are within expected values and conform to previous measurements in Piti Canal (Marsh, 1977). Integrated water motion data are listed in Table 17. The use of clod-cards constructed of an improved formulation has a wide application for future marine survey efforts. An integrated water motion value extended from a period of several hours (Muus, 1968; Doty, 1971) to a period of several days (this report) is a highly useful quantified measurement. The effect of water motion at a specific site is a highly important factor relating to occurrence, distribution, life history, larval dispersion, survival, etc. for the extant marine community. A description of the clod-card technique is given in Appendix A.

The overall water quality observed in the Piti intake areas typified a relatively healthy, productive near-shore reef ecosystem. The distribution of marine biota inhabiting Piti intake environments are apparently influenced much more by substrate and habitat availability than by the water quality of the area.

Table 16. Summary of maximum-minimum temperature data from five stations during the Piti Power Plant Intake Survey, November, 1977.

Station 7		Station 8		Station 9	
Date/Time	Max/Min	Date/Time	Max/Min	Date/Time	Max/Min
7 Nov/0945	–	6 Nov/1220	–	7 Nov/1030	–
10 Nov/1320	31.5/29.6	7 Nov/1000	30.2/29.2	10 Nov/1350	30.6/29.7
11 Nov/1005	29.0/28.7	10 Nov/1235	31.5/29.4	11 Nov/1130	30.5/28.2
13 Nov/1600	31.5/29.5	11 Nov/1110	31.5/29.2	13 Nov/1630	30.5/29.8
15 Nov/0925	28.8/26.5	13 Nov/1605	30.1/29.7	15 Nov/1005	29.8/28.1
		15 Nov/0945	30.0/28.2		

Table 16. (continued)

Station 9A		Station 11	
Date/Time	Max/Min	Date/Time	Max/Min
7 Nov/1050	–	7 Nov/1040	–
10 Nov/1355	31.5/28.0	10 Nov/1400	33.0/28.5
11 Nov/1140	30.9/28.2	11 Nov/1140	33.2/31.0
13 Nov/1625	30.5/29.8	13 Nov/1715	33.8/27.2
15 Nov/1000	31.0/27.8	15 Nov/1015	33.0/28.5

Table 17. Summary of integrated water motion data (cm/sec) from clod-card measurements made during the Piti Power Plant Intake Survey, November, 1977. (Exposure times expressed in hours:minutes)

Station	5–7 Nov Exposure Time/Rate	11–13 Nov Exposure Time/Rate	11–13 Nov Exposure Time/Rate	Weighted Average (cm/sec)
1	43:45 / 11.81	52:55 / 4.03	43:35 / 4.86	6.71
2	* 141:15 / 9.59	53:00 / 6.25	43:25 / 10.14	8.95
3	44:00 / 7.64	52:55 / 5.97	43:40 / 7.92	7.10
4	44:20 / 12.09	52:45 / 8.75	43:30 / 9.87	10.15
5	---------	53:15 / 15.70	41:40 / 23.77	19.24
6	44:30 / 8.47	52:45 / 5.41	43:30 / 3.75	5.86
7	**117:10 / 10.70	52:45 / 14.87	41:25 / 13.48	12.29
8	42:10 / 8.20	52:55 / 8.47	41:40 / 12.09	9.48
9	41:50 / 8.75	53:00 / 7.64	41:35 / 9.03	8.40
11	41:40 / 2.65	94:35 / 3.19	---------	3.02

* Exposed 5–11 Nov.
** Exposed 5–10 Nov.

REPRESENTATIVE IMPORTANT SPECIES

Fifteen taxa which have been selected as representative important species inhabiting the Piti intake environments are listed in Table 18. These forms represent a wide range of feeding types, habitat requirements, taxonomic diversity and environmental requirements. The list includes four fishes, one polychaete, two echinoderms (one holothurian and one echinoid), one hermatypic coral, one alcyonarian (soft) coral, one gastropod mollusc, one chlorophyte alga and four meroplanktonic groups. Each of these organisms functions in the maintenance of a balanced indigenous population inhabiting the Piti intake environment.

Table 18. Candidate Selected Important Species Observed during the Piti Power Plant Intake Survey, November, 1977.

Taxa	Common Name	Feeding Type	Remarks
Paramia quinquelineata	Cardinalfish	Carnivore	
Dascyllus aruanus	Damselfish	Planktivore	
Scarus sordidus (juv.)	Parrotfish	Omnivore	
Acanthurus triostegus	Surgeonfish; convict tang	Herbivore	
Sabellastarte indica	Fan worm; polychaete	Filter feeder	
Holothuria atra	Sea cucumber long spined	Detritivore	
Pocillopora damicornis	Branching stony coral	Filter Feeder	Habitat former
Sinularia polydactyla	Soft coral; alcyonarian	Filter Feeder	Habitat former
Strombus luhuanus	Gastropod mollusk	Herbivore	
Halimeda macroloba	Green alga	- - - - -	Habitat former
Various meroplankton	Polychaete larvae, Gastropod larvae (veligers) Barnacle larvae (nauplii & cyprids) Decapod larvae (crab zoea & shrimp mysis)		

Paramia quinquelineata Cuvier and Valenciennes is a voracious nocturnal carnivore (Hiatt and Strasburg, 1960). Principal food items are reported to be fishes (especially eleotrids and gobies) and decapod crustaceans. This species is reported to commonly occur among the elongated spines of the urchins *Diadema setosum* and *Echinothrix diadema*; however, this association was seldom seen during the present survey. Although small in size (5–15 cm in length), *P. quinquelineata* is a numerically abundant form in the Piti intake areas. Piti Canal is considered to be an especially suitable habitat for this species. The numerous rock overhangs, crevices and other microtopographic irregularities present in Piti Canal provide prime habitat for *P. quinquelineata*.

Dascyllus aruanus (Linnaeus), a gregarious pomacentrid is found in small aggregations (5–15 individuals) among living coral such as *Acropora* or associated with vertical structures such as pilings, bar grates, etc. in Piti Canal and Tepungan Channel. *D. aruanus* is one of the most numerous fish species in the study area. Data from zooplankton sampling during this study indicate there is an abundance of primary food organisms such as calanoid copepods, crab zoea and shrimp mysis for this nocturnal planktivore. Both Piti Canal and Tepungan Channel provide suitable habitat for *D. aruanus*.

Juvenile *Scarus sordidus* Forskal are common in Piti intake environments. This species of parrotfish is omnivorous as a juvenile (Hiatt and Strasburg, 1960); however, as an adult *S. sordidus* feeds primarily on living coral. The intake environments are probable nursery areas for this species as no adults were observed during this study. Impact on this species by the existing Piti intakes is considered minimal.

Acanthurus triostegus (Linnaeus), the convict tang or "manini" is a browsing herbivore, feeding primarily on filamentous algae. Often occurring in large schools, this species is representative of productive coral reef environments. As indicated by fouling panel data collected during this survey an abundance of filamentous algae provides a source of food for this species. The seaward areas of Piti Canal and Tepungan Channel provide excellent habitat for *A. triostegus*.

Sabellastarte indica (Savigny) is a filter-feeding polychaete fanworm which has been observed throughout the Piti intake areas. This sedentary species occupies a leathery tube which is usually attached to some hard substrate. *S. indica* was observed most often along the vertical or diagonal sides of Piti Canal or under large rocks or boulders in Tepungan Channel. These areas provide highly suitable habitat for this species, which apparently thrives in areas of good water circulation.

The sea cucumber, *Holothuria atra* (Jaeger) is a benthic detritivore. This blackish holothurian was often observed along sandy and rubble bottom areas in both Piti Canal and Tepungan Channel. A diagnostic characteristic for the identification of this species are 4–5 pairs of bare spots or patches dorsally, the remainder of the body being covered by a layer of sand. This species apparently is provided with highly suitable habitat in the Piti intake environments, especially in areas where pockets of benthic detritus have accumulated.

Diadema setosum (Leske), the long-spined sea urchin was observed in dense concentrations (up to 25/square meter) throughout Piti Canal and Tepungan Channel. This species is reportedly an omnivorous scavenger, feeding on silt, detritus and algae scraped from rocks (Pearse and Arch, 1969). Aggregations of this species in the Piti intake environments can be

described as a nuisance, especially to divers. Grazing observed on fouling panels exposed at Station 7 (Piti Canal) are probably the result of feeding behavior of *D. setosum*. The intake environments provide an ideal habitat for this gregarious species.

Many colonies of *Pocillopora damicornis* (Linnaeus), a branching stony coral, were observed in Piti Canal and Tepungan Channel environments. As reported previously (Marsh, 1977), the settlement of many new colonies of this species occurred during the summer of 1976. Many of these colonies were apparently thriving in the Piti intake areas. This species provides additional habitat for fishes such as *Dascyllus aruanus* and *Chromis caeruleus* as well as several species of decapod crustaceans. The Piti intake areas support an extensive, viable population of this coral species.

The soft coral, *Sinularia polydactyla* (Ehrenberg) was one of the few sessile organisms observed to colonize the unstable slope areas in Tepungan Channel. This species was also seen at several locations in Piti Canal. *S. polydactyla* was observed to be associated with algae such as *Caulerpa* or *Halimeda*. *S. polydactyla* provides additional habitat for various mollusks and certain algal species in the Piti intake environments.

The blood-mouth conch, *Strombus luhuanus* (Linnaeus) was abundant in the study area. This species is a herbivorous gastropod mollusc which is most commonly found along the sandy bottom areas of Piti Canal and Tepungan Channel. The shells of dead *S. luhuanus* are commonly colonized by hermit crabs in the study area. As a habitat for this species, the Piti intake environments are considered highly suitable.

Halimeda macroloba Decaisne, a chlorophyte alga is a major benthic habitat former (calcium carbonate deposition) throughout the Indo-Pacific region (Merten, 1971). This species was a common benthic algae, typical of most Piti intake sandy bottom environments. The U.S.O. beach, adjacent to Tepungan Channel is reported to support one of the richest stands of *H. macroloba* on Guam (Merten, 1971). Several distributionally associated floral species observed with *H. macroloba* were *Enhalus acoroides*, *Halophila minor*, *Caulerpa sertularioides*, *Avrainvillea obscura* and *Halimeda opuntia*. This association was most prevalent in the Tepungan Channel reef slope environments. This Piti intake area is highly suitable for this species, supporting luxurient stands of *H. macroloba*.

The meroplanktonic groups, polychaete larvae, gastropod veligers, barnacle larvae and decapod larvae were abundant in zooplankton collections, especially in Piti Canal. These larval forms are probably the single group of marine organisms which directly experience adverse impacts from the Piti intake structures. The extent of this impact is not considered large, however, for the reasons presented in the general discussion of zooplankton sampling results.

There are no threatened or endangered species of marine or terrestrial organisms in the Piti intake areas (Federal Register, 1977; fonecon with Endangered Species Office, Honolulu). The organisms discussed above were selected to provide a realistic discussion of potential intake impacts on the indigenous marine community inhabiting the Piti intake environments.

NARRATIVE SUMMARY

The marine environmental impact caused by existing cooling water intake structures for Piti Power Plant was assessed through the analysis and evaluation of data collected during an on-site field survey in November, 1977. These data indicate that the design of Piti intake structures minimizes potential adverse impacts on the majority of marine biota in the study area.

The construction of intake structures which draw cooling water from an open coastal region rather than from an estuarine environment exemplifies favorable planning and design to minimize adverse environmental impact. The series of elongated waterways (Tepungan Channel and Piti Canals with various bifurcations) further reduces adverse impacts by providing added settlement surfaces for many potentially entrainable meroplanktonic forms. Additionally, these waterways provide suitable substrate and habitat for many macroinvertebrate species. Flow velocities are reduced by the large dimension intake structures, thus significantly minimizing adverse impingement effects.

The distribution of some forms is enhanced by increased habitat availability and amplified water circulation. Marsh *et al.* (1977) observed that operations of both Piti and Cabras Island Power Plants have increased water circulation in Apra Harbor and probably enhance water clarity in the outfall lagoon by transporting finer suspended particles out of the area. These factors are beneficial for some organisms and inhibitory to others. Observations of biota inhabiting the Piti intake environments suggest that minimal adverse effect is attributable to the design or operation of the intake structures.

Plankton data collected during the present survey provide an initial examination of potential entrainment effects caused by the Piti Power Plant. Comparisons of zooplankton data collected from the intake areas with that of the more estuarine power plant outfall environments in Apra Harbor (Marsh, 1977) does not support Marsh's conclusion that a much poorer zooplankton community exists in the intake areas. However, it is suggested that the large oceanic recruitment region on the western side of Guam is not significantly affected by Piti Power Plant cooling water entrainment phenomena.

Impingement of marine fauna was minimal during the study period. Observations after a tropical storm showed an increase of impinged drift algae on the traveling screens, but faunal components of impinged biota remained insignificant.

An examination of selected representative important species of marine biota in the Piti intake environments indicates that many components of the marine community are provided with additional suitable habitat by the intake waterways and associated structures. Only minimal adverse effects are attributable to the Piti intakes when all fifteen representative taxa are considered.

The larval stages of most selected species experience some mortality due directly to entrainment effects. Also the holoplankton (such as copepods, medusae and chaetognaths) similarly experience these effects. However, zooplankton collections at the Piti outfalls indicate that some mero- and holoplankton survive passage through the plant. Another minor adverse effect is the fish and macroinvertebrate mortality caused by impingement. This phenomenon is considered insignificant to the intake area ecosystem.

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APPENDIX A

MEASUREMENT OF WATER MOTION WITH A NEW FORMULATION OF CLOD-CARD

Water motion has long been recognized as a factor which has strong influence on the distribution and growth of nearly all marine organisms. However, until recently, the lack of a simple means of measuring water motion, particularly in shallow water environments, has impeded the study of such effects. Most conventional current meters are only capable of measuring low-turbulence currents of moderate to high velocity which are slow-changing or unchanging in direction. In 1968 Muus introduced a novel method for the measurement of turbulent water motion. He utilized the dissolution and attendant weight loss of calcium sulfate (plaster of Paris) balls mounted on the ends of pieces of rigid wire as a quantitative expression of water motion or "exposure" of various localities. Doty (1971) modified the method slightly by using calcium sulfate oblong-shaped "clods" molded in ice cube trays. Each clod was cemented onto a plastic card (thus the term "clod-card") to provide a convenient attachment and labeling surface.

Muus determined the relationship between current velocity and dissolution rate of the calcium sulfate balls in a small, water-filled canal in which flow rate could be regulated. At flow rates of 5, 10 and 15 cm/sec, balls of 6.0g starting weight showed respective weight losses of 0.17, 0.27 and 0.35 g/hr at about 23°C.

Doty preferred the use of a "diffusion index." This can be obtained by first determining the still-water (no motion) weight loss value for the particular set of clod-cards. That value is then divided into the field weight loss of individual clod-cards to yield the diffusion indices. Although Doty's method provided only a relative measure of water motion differences, it had the advantage of not requiring the time and equipment needed to obtain absolute calibration values.

A major problem that both Muus and Doty reported was frequent variability in weight loss of identical lots of clods or balls under similar water motion conditions. The greater losses were attributed to loss of solid pieces from the clods' surfaces. In some cases, significant abrasion was also suspected. Another problem that has come to the author's attention is the extreme variability in solubility of various batches of hardened calcium sulfate. These differences may result from variations in chemical composition and crystal size between batches of different producers. One example of this kind of variation was seen in the calibration of a batch of clod-cards which was used by P. Jokiel and R. Brock in a field survey at Johnston Island. The dissolution rates of their clods were found to be nearly ten times higher than those reported by Muus.

In light of the problems experienced with calcium sulfate clod-cards, the author has experimented with a formulation consisting of Fixall^{R}[1] and Weldwood^{R}[2] plastic resin glue. The exact proportions of materials used are: 1 part glue, 5.1 parts water, and 10.5 parts Fixall. The Fixall and glue powders are mixed together first and then water is added. Mixing with the water is done carefully to minimize entrapment of air bubbles. The mix is poured into one-piece, compartmented ice cube trays and allowed to set for 48 hours at room temperature (about 23°C). The flat bases of all clods are then sanded to bring the entire lot of clods within 0.5g of a predetermined weight. Next, the clods are glued to cards made of any handy water-resistant material such as plastic, metal or wood. Before use, the clod-cards are soaked in a container of seawater for 24 hours, rinsed, blotted dry and weighed to a tenth of a gram. This initial weight is written on the card along with an assigned identification number. After soaking and prior to field use, the clod-cards are wrapped in moist fabric and stored in closed containers. In the field the clod-cards can be secured to such objects as stakes, bricks and pilings. Following exposure times of several hours to several days (dependent on the intensity of water motion in the area) the clod-cards are removed, blotted dry and reweighed. The rates of weight loss, usually expressed as grams per hour, are then converted to current velocities if the required calibration data are available. Alternatively, diffusion indices can be calculated (Doty, ibid.) after obtaining a still-water value for the clod-card lot.

To date Fixall formulation clod-cards have been used by the author in a number of field and laboratory studies. Refer to Figure A–1 for dimensions and shape of a typical Fixall formulation clod-card. Various lots of clod-cards made at different times with batches of Fixall purchased from different distributors have produced statistically similar calibration data (for example, see Figure A–2). Of greater significance is the fact that intra-lot Fixall clod-cards show similar weight losses under the same water-motion conditions. This higher reliability (as compared to calcium sulfate clod-cards) is likely due to the denser, less friable nature of the Fixall clods. Fracturing and loss of chunk-like masses has never been observed on Fixall clods.

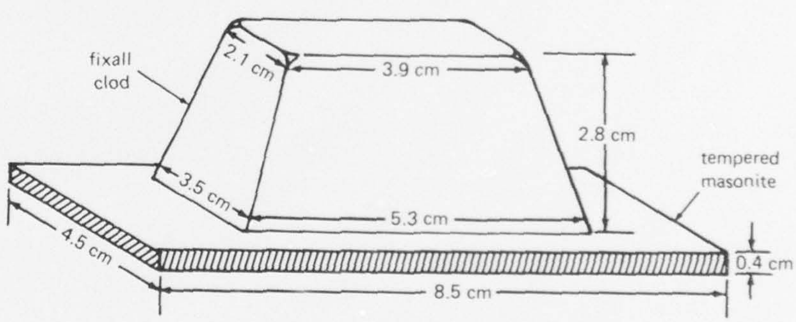

Figure A-1. Dimensions and shape of a typical clod-card used during the Piti Power Plant Intake Survey, November, 1977.

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[1] A powder compound which is mixed with water and is used like spackling for various filling and patching applications. It is nearly similar to plaster of Paris in appearance and working consistency. Manufactured by Dowman Products Inc., Long Beach, CA 90813.

[2] Distributed by Weldwood Packaged Products, Chemware Group, Champion Int. Corp., Kalamazoo, Michigan 49003.

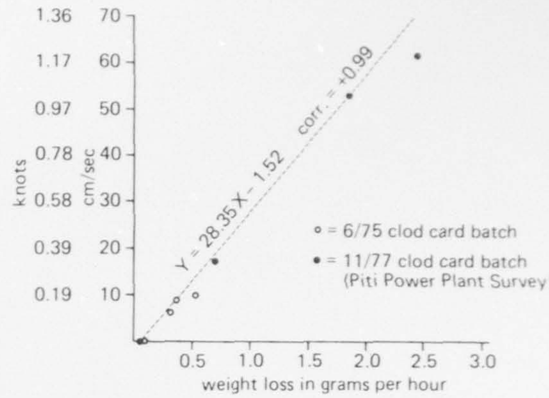

Figure A-2. Calibration of Fixall formulation clod-cards used during the Piti Power Plant Intake Survey, November, 1977.

As a clod decreases in weight (and surface area) its rate of weight loss also decreases. Time series plots of weight loss on clods in still water (Figure A-3) show that weight loss is linear through the dissolution of 60% of the clod's weight. Significant departures from linearity do occur in rate of weight loss when the clod has lost more than 80% of initial weight. Therefore, when clod-cards are used in an area where current velocities are estimated to exceed 15 cm/sec, the clods should be checked for weight loss after 24 hours. Other sources of variation in weight loss such as salinity and temperature are discussed by Doty (ibid.)

The calibration data for Fixall clod-cards in Figure A-2 were derived using two different batches of clods and two different water motion exposure methods. Clod-cards 1 through 5 were placed on stakes at various points immediately downstream of a power plant cooling water discharge pipe. Exposure times were 5.5 hours. Current velocities at each clod-card site were checked using both a General Oceanics (Model 2030 R2) digital current

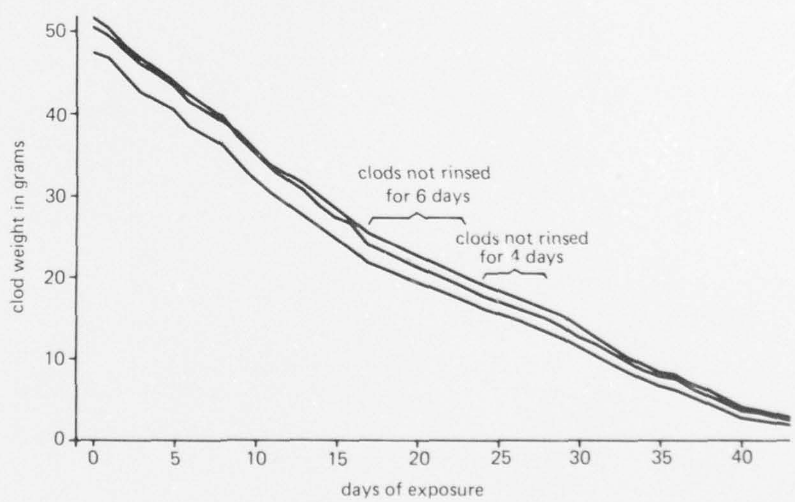

Figure A-3. Weight loss data for Fixall formulation clod-card under still water conditions. Piti Power Plant Intake Survey, November, 1977. (Experimental data obtained in Hawaii)

meter and measurement of transit times of a neutrally buoyant object over a 10 meter distance. Clod-cards 6 through 9 were placed inside 7.62cm diameter pipes through which closely controlled flows of seawater were maintained. Exposure periods were 69.5 hours.

Still-water values for both batches were obtained by following weight losses of clod-cards immersed in 10 liter buckets of seawater maintained at typical field use temperatures. For a period of four to five days the seawater was changed daily and the clod-cards were rinsed gently to remove any accumulated detrital or bacterial films. After five to six days the clod-cards were weighed.

References:

Doty, M. S., Measurement of Water Movement in Reference to Benthic Algal Growth. Botanica Marina, Vol XIV, p. 32-35, 1971.

Muus, B. J., A Field Method for Measuring "Exposure" by Means of Plaster Balls. A Preliminary Account. Sarsia, Vol. 34, p. 61-68, 1968.

APPENDIX B

CHECKLIST OF PLANKTONIC BIOTA IDENTIFIED FROM SAMPLES COLLECTED DURING THE PITI POWER PLANT INTAKE SURVEY, NOVEMBER 1977.

Location Legend: PC=Piti Canal; ITC=Inner Tepungan Channel; OTC=Outer Tepungan Channel; OL=Outfall Lagoon.

Taxa	Location
Pyrrophyta (Dinoflagellates)	
Dynophyceae	
Peridinales	
Ceratium sp.	PC/ITC/OTC
Protozoa	
Foraminifera	
Species A *?Tretomphalus*	All
Species B "star" *?Calcarina*	All
Species C "spearhead" *?Triloculina*	All
Species D "paper shell" *?Amphisorus*	All
Rotifera	OL
Cnidaria	
Siphonophora	PC/ITC/OTC
Medusae	All
Nematoda	All
Annelida	
Polychaete larvae	All
Arthropoda/Crustacea	
Diplostraca	
Cladocera	
Evadne sp.	PC/ITC/OTC
Ostracoda	All
Copepoda	
Calanoida	
Acartia sp.	All
Acrocalanus spp.	All
Candacia sp.	OTC/OL
Calanus sp.	All
Calocalanus pavo (Dana)	All
Calocalanus sp.	All
Clausocalanus spp.	All
Centropages orsinii (Giesbrecht)	All

Taxa	Location
Euchaeta sp.	PC
"Gaetanus"-like sp.	PC/ITC/OTC
Labidocera sp.	All
Lucicutia sp.	All
Mecynocera clausi Thompson	All
Paracalanus sp.	All
Pontellina sp.	ITC/OL
Tortanus sp.	PC/ITC/OL
Arthropoda/Crustacea	
Copepoda	
Calanoida (continued)	
Undinula darwini (Lubbock)	All
Undinula vulgaris (Dana)	OL
Undinula spp. (juveniles)	All
Unidentified calanoid juveniles	PC/ITC/OTC
Calanoid nauplii	ITC/OTC
Cyclopoida	
Corycaeus spp.	All
Lubbockia squillimana Claus	PC/ITC/OTC
Oithona plumifera Baird	All
Oithona simplex Farran	All
Oithona sp.	ITC/OTC
Oncaea spp.	All
Unidentified cyclopoids	OL
Harpacticoida	
Metis sp.	PC/ITC/OL
Microsetella norvegica (Boeck)	ITC
Microsetella rosea (Dana)	PC/ITC/OL
Porcellidium sp.	All
Zaus sp.	All
Unidentified harpacticoids	All
Monstrilloida	OTC
Caligoida	PC/OTC/OL
Cirripedia	
Nauplii A "small, slender"	All
Nauplii B "stout"	All
Cypris larvae	All
Malacostraca	
Cumacea	PC/OL
Isopoda	All
Amphipoda	
Gammaridea (several species)	All
Decapoda	
Shrimp mysis	All
Crab zoea	All
Crab megalops	PC/ITC/OL
Stomatopoda	
Stomatopod alima larvae	PC

Taxa	Location
Mollusca	
Gastropoda	
Gastropod veliger larvae	All
Bivalvia (=Pelecypoda)	
Bivalve veliger larvae	PC/ITC/OL
Unidentified veliger larvae	All
Echinodermata	
Echinoderm larvae	PC/ITC/OTC
Chaetognatha	
Sagitta enflata Grassi	All
Sagitta sp.	All
Chordata	
Urochordata	
Ascidacea	
Ascidian larvae	OL
Larvacea	
Oikopleura sp.	PC/ITC/OTC
Vertebrata	
Osteichthyes	
Fish larvae	All
Fish eggs "oval"	All
Fish eggs "round"	All

APPENDIX C

CHECKLIST OF FISHES SITED IN PITI CANAL (PC) & TEPUNGAN CHANNEL (T NOVEMBER 1977.

TNTC=Too Numerous to Count, D=Dominant (10+), C=Common (6–10), P=Present (2–5), R=Rare (1).

Family/Genus & Species	PC	TC
Acanthuridae		
Acanthurus triostegus (L.)	P	C
Acanthurus xanthopterus (C & V)	P	C
Naso lituratus (B & S)	–	P
Apogonidae		
Apogon novemfasciatus C & V	P	C
Paramia quinquelineata (C & V)	C	P
Aulostomidae		
Aulostomus chinensis (L.)	R	P
Balistidae		
Balistoides viridescens (B & S)	–	R
Rhinecanthus aculeatus (L.)	P	TNTC
Rhinecanthus retangulatus (B & S)	–	P
Belonidae		
unidentified belonid	–	R
Blennidae		
Aspidontis taeniatus Q & G	R	P
Salarias fasciatus (Bloch)	–	C
Bothidae		
Bothus ?pantherinus (Ruppell)	–	R
Canthigasteridae		
Canthigaster solandri (Richardson)	C	C
Canthigaster bennetti (Bleeker)	P	R
Carangidae		
Caranx sp. (probably *C. melampygus* Cuvier)	P	C
Scomberoides sancti-petri (Cuvier)	–	P

Family/Genus & Species	PC	TC
Chaetodontidae		
Chaetodon auriga Forskal	C	P
Chaetodon lunula (Lacepede)	P	P
Chaetodon ulietensis Cuvier	C	P
Eleotridae		
Asterropteryx semipunctatus Ruppell	P	C
Ptereleotris microlepis (Bleeker)	–	P
unidentified eleotrid (dark w/white margin of dorsal fin)	–	R
Gobiidae		
unidentified goby (associated w/burrows)	C	TNTC
Fistulariidae		
Fistularia petimba Lacepede	–	R
Hemiramphidae		
Hyporhamphus sp.	P	P
Holocentridae		
Flammeo sammara (Forskal)	P	P
Myripristis sp.	P	P
Kuhliidae		
Kuhlia taeniura (C & V)	P	–
Kyphosidae		
Kyphosus cinerascens Forskal	–	P
Labridae		
Bodianus sp.	–	R
Chelio inermis (Forskal)	R	P
Epibulus insidiator (Pallas)	P	–
Gomphosus varius Lacepede	R	P
Halichoeres trimaculatus (Q & G)	C	C
Labroides dimidiatus (C & V)	R	P
Stethojulis bandanensis Bleeker	P	P
Leiognathidae		
Leiognathus equula (Forskal)	P	–
Lutjanidae		
Lethrinus sp.	P	C
Lutjanus fulvus (Q & G)	C	P
Scolopsis cancellatus (C & V)	P	–
Mugilidae		
Chelon vaigiensis (Q & G)	P	C

Family/Genus & Species	PC	TC
Mugiloididae		
Parapercis cephalopunctata (Seale)	–	C
Mullidae		
Mulloidichthys auriflamma (Forskal)	P	C
Mulloidichthys samoensis (Gunther)	C	C
Parupeneus barberinus (Lacepede)	P	C
Muraenidae		
Echidna nebulosa (Ahl)	–	P
Pempheridae		
Pempheris oualensis C & V	P	–
Pomacentridae		
Abudefduf saxatilis (Q & G)	P	–
Abudefduf septemfasciatus (C & V)	P	P
Amphiprion melanopus Bleeker	R	P
Chromis caeruleus (C & V)	P	TNTC
Dascyllus aruanus (L.)	D	D
Dascyllus trimaculatus (Ruppell)	–	P
Eupomacentrus albifasciatus (S & M)	P	C
Eupomacentrus nigricans (Lacepede)	P	C
Pomacentrus pavo (Bloch)	P	C
Scaridae		
Scarus sordidus Forskal (juveniles)	C	C
Scarus spp. (2)	P	P
Siganidae		
Siganus spinus (L.)	P	P
Syngnathidae		
unidentified syngnathid	R	P
Synodontidae		
Saurida gracilis (Q & G)	R	P
Tetraodontidae		
Arothron nigropunctatus (Schneider)	R	–
Zanclidae		
Zanclus cornutus (L.)	P	C
subtotals	50	58
total	65	

Note: Abbreviations for naming authorities used in the fish checklist are:

B & S = Bloch & Schneider; L = Linnaeus; S & M = Schlegel & Muller
C & V = Cuvier & Valenciennes; Q & G = Quoy & Gaimard

APPENDIX D

CHECKLIST OF BIOTA IDENTIFIED FROM PITI CANAL (PC) OR TEPU
CHANNEL (TC) DURING THE PITI POWER PLANT INTAKE SURVI
NOVEMBER 1977.

FLORA

Taxa
Algae
Cyanophyta (Blue-greens)
Hormothamnion enteromorphoides B & F
Microcoleus lyngbyaceus (Kutz.) Crouan
Schizothrix calcicola (Agardh) Gomont
Chlorophyta (Greens)
Avrainvillea obscura J. Agardh
Bornatella sp.
Caulerpa racemosa (Forskal) J. Agardh
Caulerpa serrulata (Forskal) J. Agardh
Caulerpa verticillata J. Agardh
?*Cladophora* sp.
Enteromorpha clathrata (Roth) Agardh
Halimeda macroloba Decaisne
Halimeda opuntia (L.) Lamouroux
Neomeris annulata Dickie
Chrysophyta (Diatoms; from fouling panels)
Coscinodiscus sp.
Grammotophora sp.
Licomorpha sp.
Navicula sp.
Nitzschia sp.
Stictocyclus sp.
Phaeophyta (Browns)
Dictyota bartayresii Lamouroux
Ectocarpus sp.
Hydroclathrus clathratus (C. Agardh) Howe
Lobophora variegata (Lamouroux) Womersly
Padina tenuis Bory
Sargassum polycystum C. Agardh
Rhodophyta (Reds)
Amphiroa foliacea Lamouroux
Centrocerus clavulatum (C. Agardh) Montagne
Gelidiella acerosa (Forskal) Feldm. & Hamel
Gracillaria sp.
Hildenbrandia sp.
Polysiphonia tepida Hollenberg

Taxa	Location
Seagrasses	
Anthophyta (=Magnoliophyta)	
Enhalus acoroides (L. f.) Royle	TC
Halophila minor (Zoll.) Hartog	TC

FAUNA

Taxa	Location
Protozoa	
Foraminifera	
Amphisorus hemprichii Ehrenberg	TC
Amphistegina lessonii d'Orbigny	TC
Baculogypsina sphaerulata Parker & Jones	TC
Calcarina spengleri (Gmelin)	TC
Peneropolis pertusus (Forskal)	TC
Tretemphalus bulloides (d'Orbigny)	TC
Triloculina sp. cf. *T. trigonula*	TC
Porifera (Sponges)	
Unidentified demospongia	TC & PC
Cnidaria	
Hydrozoa (Hydroids; Fire Coral)	
Dynamena crisioides Lamouroux	PC
Hebella sp. cf. *H. muscensis*	PC
Millepora sp.	TC
Schyphozoa (Jellyfishes)	
Cassiopea andromeda (Forskal)	PC
Unidentified scyphozoan (photo)	TC
Anthozoa (Anemones, soft corals & stony corals)	
Calliactis polypus (Forskal) (on hermit crab shell)	TC
Sinularia polydactyla (Ehrenberg)	TC & PC
Acropora sp.	TC & PC
Favites sp.	TC & PC
Leptastrea purpurea (Dana)	TC
Pavona sp.	TC
Pocillopora damicornis (Linnaeus)	TC & PC
Porites lutea Milne-Edwards & Haime	TC

Taxa	Location
Annelida	
Polychaeta (Marine segmented worms)	
Aphroditidae (Polynoinae)	TC
Armandia sp.	PC
Cirriformia sp.	TC
Eurythoe complanata (Pallas)	TC
Glycera sp.	PC
Glycerid larvae	PC
Nematoneries unicornis Day	TC
Nereidae (several unidentified species)	TC
Polydora sp. (juvenile)	TC
Sabellastarte indica (Savigny)	TC & PC
Sphaerosyllis sp.	TC
Spirobranchus giganteus (Pallas)	TC
Terebellidae (photo)	TC
Arthropoda/Crustacea	
Tanaidacea	
Leptochelia spp. (2)	TC & PC
Isopoda	
Gnathia sp.	TC
Amphipoda/Gammaridea	
Amphilochiidae (several unidentified specimens)	PC
Cymadusa sp.	TC
Ischyrocerus sp. cf. *I. oahuensis*	PC
Anomura/Reptantia	
Alpheus pacificus Dana	TC
Callianassa sp.	TC
Dardanus sp.	TC & PC
Stenopus hispidus (Olivier)	PC
Brachyura/Reptantia	
Actaea tomentosa (Milne-Edwards)	TC
Trapezia sp.	TC
Stomatopoda	
Unidentified species (observed)	TC & PC
Mollusca	
Gastropoda (Snails)	
Architechtonica sp.	TC
Cerithium spp. (2)	TC & PC
Chicoreus(=Murex) sp.	PC
Conus ebraeus Linnaeus	TC
Conus leopardus Roeding	TC
Cymatium pileare (Linneaus)	TC
Cypraea annulus Linnaeus	TC & PC
Cypraea caputserpentis (Linnaeus)	TC
Cypraea erosa Linnaeus	TC
Cypraea moneta Linnaeus	TC
Drupa rubusidaeus Roeding	TC
Drupa ricinus (Linnaeus)	TC

Taxa	Location
Lambis lambis Linnaeus	TC
Mitra ferruginea Lamarck	TC & PC
Nerita plicata Linnaeus	TC & PC
Polinices melanostomus (Gmelin)	TC
Strombus luhuanus Linnaeus	TC & PC
Terebra maculata (Linnaeus)	TC
Terebra subulata (Linnaeus)	TC
Trochus niloticus Linnaeus	TC & PC
Bivalvia (clams & oysters)	
Ctena sp. cf. *C. bella*	TC
Gafrarium sp.	TC & PC
Pinctada margaritifera Linnaeus	TC
Pinna muricata Linnaeus	TC & PC
Saxostrea mordax (Gould)	TC & PC
Tellina sp.	TC
Amphineura (Chitons)	
Acanthochiton sp.	TC
Echinodermata	
Asteroida (Starfish)	
Culcita novaguineae Muller & Troschel	TC
Linckia laevigata (Linnaeus)	TC & PC
Linckia multifora (Lamarck)	TC
Echinoida (Sea urchins)	
Diadema savignyi Michelin	TC & PC
Diadema setosum (Leske)	TC & PC
Echinometra mathei (deBlainville)	TC & PC
Echinothrix calamaris (Pallas)	TC
Echinothrix diadema (Linnaeus)	TC
Tripneustes gratilla (Linnaeus)	TC
Toxopneustes pileolus (Lamarck)	PC
Holothuroidea (Sea cucumbers)	
Actinopyga mauritiana (Quoy & Gaimard)	TC & PC
Bohadschia argus (Jaeger)	TC
Chirodota rigida Semper	TC
Euapta godeffroyi (Semper)	TC
Holothuria cinerascens (Brandt)	TC & PC
Opheodesoma grisea (Semper)	TC
Stichopus chloronotus Brandt	TC & PC
Hemichordata	
Unidentified Enteropneusta (acorn worms)	TC
Urochordata	
Unidentified Ascidacea (tunicates)	TC

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